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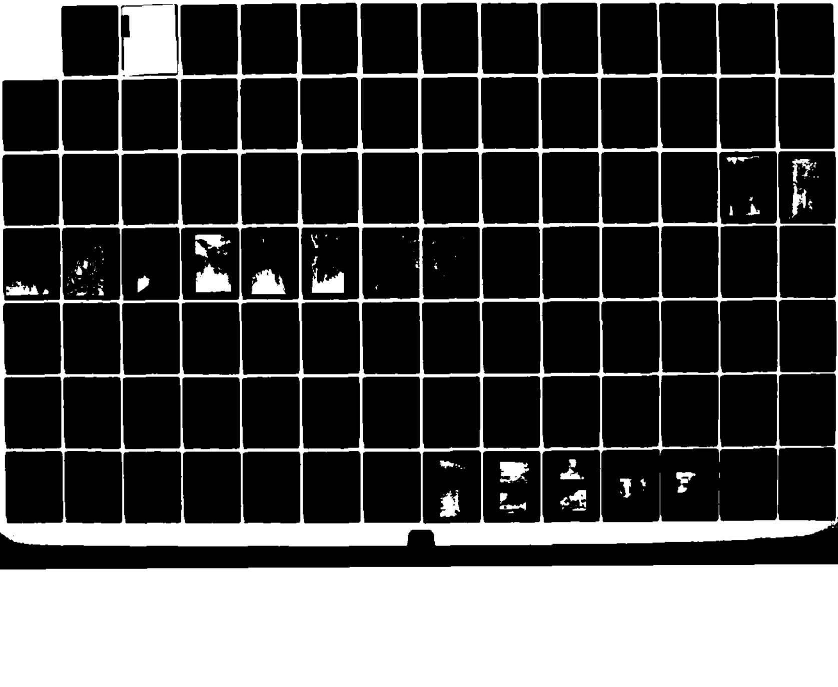

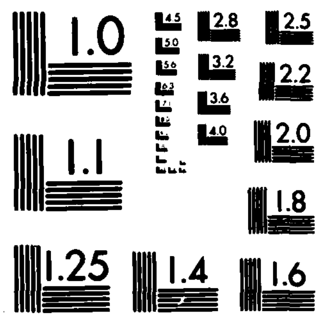

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18. SUPPLEMENTARY NOTES

This report was originally published in January 1954. The report has been reprinted with the addition of Appendix A, Extension of Grout Curtain.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report includes a brief history of the project, a description of the dam and appurtenant works, descriptions of the regional and local geology of the area, and a complete discussion of the methods of foundation treatment, including the 1978-79 extension of the left abutment grout curtain. Included are representative drawings of foundation features and photographs of various aspects of the foundation and foundation treatment.

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Corps of Engineers

Fort Peck District

FOUNDATION REPORT
COLD BROOK DAM

Hot Springs, South Dakota
January 1954

Revised with Appendix A
Omaha District
December 1983

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FOUNDATION REPORT
COLD BROOK DAM
HOT SPRINGS, SOUTH DAKOTA

I

1.1. Purpose. For many years engineers and others, whose duties entail the planning, design, construction, and operation of all types of engineering structures, have fully recognized the importance of preparing complete and competent "as built" records of these structures for future reference. Since the soil or rock mass upon which a structure is founded comprises an integral and highly important part of the structure, it has become a policy of the Corps of Engineers to prepare, in addition to the "as built" records of surficial features, a complete record report of that portion of the structure which exists below the surface of the ground, that is, the foundation upon which the structure depends for support and stability. The following report comprises the foundation record of Cold Brook Dam near Hot Springs, South Dakota. The text includes a brief history of the project, a description of the dam and appurtenant works, descriptions of the regional and local geology of the area, and a complete discussion of the methods of foundation treatment. Included also are representative drawings of foundation features and photographs of various aspects of the foundation and foundation treatment.

1.2. Location and General Description. Cold Brook Dam is situated in Fall River County, South Dakota on Cold Brook Creek, a tributary of Fall River. The axis of the dam is located a mile and a quarter north of the confluence of Cold Brook and Hot Brook Creeks which unite to form Fall River at the north edge of the town of Hot Springs, South Dakota. Cold Brook Dam and Reservoir in combination with the related units of the overall project, Cottonwood Springs Creek Dam (proposed) and the presently completed improvement of Fall River Channel through the city of Hot Springs, will provide a high degree of flood protection for the city and adjacent rural areas. The dam consists of a rolled earth fill embankment having a maximum height of 129 feet and a total length of 920 feet. The upstream and downstream slopes are symmetrical and progress downward from the crest on a 1 on 2.5 slope for approximately 40 feet and thence on a 1 on 3 slope to the toe of the embankment. Underseepage through the alluvial materials in the dam foundation is controlled by a rolled fill cutoff which extends from crest elevation at the left abutment across the valley to crest elevation at the right abutment. The base of the cutoff is founded in bedrock throughout the entire length. The minimum base width of the cutoff is 20 feet and the sides slope upward on a 1 on 1-1/2 slope except where the cutoff extends five feet or more into bedrock. In these areas the portion of the cutoff below the bedrock surface possesses 4 on 1 slopes. Discharge of all but extremely high flood flows from Cold Brook Basin is provided for by means of a concrete intake structure and a horseshoe shaped conduit which passes beneath the dam. Excess flow from maximum flood runoffs will be diverted through an uncontrolled spillway located in a divide on the east side of the reservoir rim.

1.3. Historical. A study of the Fall River Basin, of which Cold Brook Creek is an integral part, is contained in the congressional "308 Report" published as House Document No. 190, Seventy-second Congress, first session, entitled: "Cheyenne River, South Dakota and Wyoming." That report is concerned with problems of the basin as a whole and does not present any detailed information concerning flood control problems in the vicinity of Hot Springs, South Dakota. A report reviewing the above mentioned report was published as House Document No. 655, Seventy-sixth Congress, third session, entitled: "Fall River and Beaver Creek, South Dakota." This report presented a plan for providing limited protection from floods in Hot Springs, South Dakota and vicinity. The plan includes provisions for channel improvements of Fall River through the town of Hot Springs and for the construction of flood control dams on Cottonwood Springs Creek and Cold Brook Creek. The overall project was authorized by the Flood Control Act approved 18 August 1941 (Public Law 228, 77th Congress, 1st Session). Work on the Cold Brook Dam unit of the project was performed in accordance with Specifications, Serial No. CIVENG-24-016-50-49, dated 24 April 1950 with funds available from appropriation 21X3113 Flood Control General, Cold Brook Reservoir, Fall River Basin, South Dakota.

Several sites were investigated to determine the most practicable location for a dam to control the flood runoff from Cold Brook Creek. The availability of suitable materials for random and impervious fill borrow material at the damsite, the existence of a suitable natural spillway site, and the availability of satisfactory rock at the site for spalls, riprap, and concrete aggregate were among the factors which led to the selection of the damsite at the present location. The first comprehensive subsurface investigations were initiated in January 1944. Additional investigations were made in 1949 and 1950 just prior to construction.

1.4. Regional Geology. Cold Brook Creek is situated on the southeastern slope of the mountainous uplift known as the Black Hills. This uplift is an irregular dome, somewhat ellipsoidal in configuration, with the longer axis extending approximately 125 miles in a northwest to southeast direction and the shorter axis extending 50 miles in a west to east direction. The Black Hills dome stands out in bold relief above the general level of the surrounding Great Plains area. The uplift has been brought about as a result of the large scale orogenic movements originating in the Tertiary epoch and resulting in the formation of the present Rocky Mountain chain of which the Black Hills of South Dakota constitutes an eastern outlier. The core of the uplift is comprised of a mass of granite and this core is surrounded by a series of pre-Cambrian crystalline rocks and nearly complete sequence of sedimentary formations ranging in age from late Cambrian to late Cretaceous. Because of extensive erosion of the uplifted area, roughly concentric outcrops of the various formations are encountered, with the oldest formation cropping out near the center. Beds of unequal hardness have eroded at different rates so that the present topography consists of a series of concentric hogbacks of hard rocks separated by valleys carved in the softer formations. The general drainage pattern is radial, so that the major streams cut accross the concentric valleys and ridges and thus flow alternately in wide valleys and through sharp water gaps and box canyons. In general, the ridges support a growth of pine and cedar, and the valleys are covered with grass, small shrubs, and occasional juniper.

II FOUNDATION EXPLORATIONS

2.1. Preliminary Explorations. Damsites investigated by core drilling included Site No. 7, which is located approximately four miles upstream from Hot Springs; upper location of Site No. 9; and lower location of Site No. 9. The upper location on Cold Brook Dam site No. 9 (approximately one and one-quarter miles north of town) was selected as being the most practicable and economic location. Subsurface explorations at this site were commenced in January 1944. At that time 18 small diameter (NX cores) holes were drilled in the vicinity of the dam and spillway and in addition, 25 auger and churn drill holes and five test pits were put down in the valley alluvium for a distance extending 3200 feet upstream from the axis to delineate the volume and classify the type of materials present. Since the data obtained from the holes put down in the alluvium indicated that a large subsurface flow of water would be encountered throughout the alluvium to bedrock, the Definite Project Report included a plan for installing a row of sheet steel piling across the valley near the upstream toe to prevent excessive underseepage. During the planning and design stage, an impervious rolled fill earth cutoff to bedrock was substituted in lieu of the proposed sheet piling cutoff as being more practicable and less expensive.

2.2. Supplementary Investigations. The original borings at the damsite disclosed that the bedrock beneath the valley consisted of brecciated and fractured sandy limestone containing open joints and minor cavities. Since it was felt that this condition might seriously effect the integrity of the dam and result in possible piping and undermining of the structure, it was requested by the Office, Chief of Engineers that additional borings be made across the valley along the centerline of the proposed cutoff trench with the view of determining whether water passages of a sufficiently large magnitude to cause piping existed. The borings would also serve to more fully delineate the configuration of the bedrock beneath the cutoff trench. In compliance with the above request, a contract was let to the Boyles Brothers Drilling Company of Salt Lake City to drill a total of 17 NX holes at the site. Drilling was commenced during the week of 3 to 10 December 1949 and was completed on 13 February 1950. Nine of these holes were drilled along the center line of the cutoff trench and 8 were drilled along the conduit centerline. A total of 285 feet of overburden (alluvium and talus) and 845 feet of limestones, shales, and sandstones was drilled under this contract. The locations of these holes are shown on Plate No. 2.

Data obtained from analysis of the drilling records and cores obtained from the supplementary borings (holes Nos. 1-17 on above mentioned drawing) indicated that the upper zone of bedrock was sufficiently jointed and fractured to warrant the construction of a shallow grout curtain beneath the cutoff trench and across the valley. Accordingly, provisions were made in the contract plans and specifications covering construction of the dam to provide for such a grout curtain beneath the dam.

III GEOLOGY OF THE DAMSITE

3.1. General. The geological formations encountered at the damsite are of sedimentary origin and are of upper Paleozoic and lower Mesozoic age.

They include in ascending order, the Minnelusa Formation (Pennsylvanian); Opeche Formation (Permian); Minnekahta Formation (Permian); and Spearfish Formation (Permo-Triassic). Pleistocene and recent stream gravels are also present above the sedimentary formations. The original geological investigations of the damsite were made by John Paul Gries, a consulting geologist, under contract with the Corps of Engineers. These investigations entailed a geological reconnaissance of the area and a detailed study of cores and drillers records of numerous holes and test pits put down at the site during the preliminary investigations in 1944. The descriptions of the various stratigraphic units which follow are largely based on the results of this early investigation by Mr. Gries, supplemented by data obtained during the drilling made in 1949 and 1950.

3.2. Stratigraphy.

(a) Minnelusa Formation. This formation constitutes the bedrock beneath the valley at the damsite. It is known from out-cropping exposures elsewhere that the Minnelusa consists of approximately 500 feet of sandstone, limestone, and shale. Throughout the greater part of the Black Hills the formation is essentially a fine-grained porous sandstone capable of imbibing much surface water and constituting one of the major artesian zones in the plains area east of the Black Hills.

The formation crops out approximately one half mile upstream from the axis but lies at a depth varying from five to thirty five feet below the surface at the dam axis. In the vicinity of Cold Brook Dam and elsewhere in the southern part of the Black Hills, the upper zone of the Minnelusa consists of brecciated and fractured limestone containing local solution cavities throughout. The limestone, which is approximately 12 to 15 feet thick throughout the major width of the valley, grades laterally into a sandy member toward the east or left side of the valley and attains a maximum thickness of 25 feet near the toe of the west or right abutment. The upper portion of the limestone on this abutment changes somewhat in lithology, becoming more clayey in character and apparently grades into a shaley member farther to the west. The limestone beneath the mid-section of the axis is highly dissolved and brecciated and in several cores it was noted that the dissolved and fractured zones have been partially or completely filled and recemented with materials derived from the overlying formations.

A zone of fine-grained orange sandstone approximately 10 to 20 feet thick lies beneath the limestone horizon and this sandstone is underlain by a zone of dense sandy limestone. The lower limestone zone is similar in lithology to the upper zone and contains many open joints and cavities. Logs of exploratory holes Nos. 3 and 5 indicated the presence of an extensive solution cavity in the lower limestone, but this cavity appears to have been refilled by an impervious limey clay.

(b) Opeche Formation. The Opeche Formation consists of purple, red, and buff or yellow shales and siltstones interspersed with thin bands of sandy and clayey vari-colored limestones and sandstones. The formation attains a thickness of approximately 145 feet and forms the valley walls at the damsite. The top of the formation is conspicuously marked by a five foot

zone of soft limey purple shale which is underlain by alternate zones of red sandy shale, limey sandstones, thin limestones, and sandstones. The sandy shale beds vary from one to four feet in thickness and are characterized by vertical joints and horizontal bedding planes filled with red clay partings.

(c) Minekahta Formation. This formation which forms the steep upper walls of the valley at the damsite, consists of about 48 feet of fine-grained, thin bedded to massive limestone; ranging in color from purple to pink to grey. It's thin bedding is characteristic, but the layers are tightly cemented together and the outcropping ledges present a massive appearance. The Minnekahta limestone forms the cap rock of the valley rim on both sides of Cold Brook Dam. Because of the eastward dip of the formations, the Minnekahta lies above the crest elevation of the dam on the west abutment, but constitutes the upper 48 feet of the east abutment (see Plate No. 3). In both outcrops and cores the formation consists of alternate members of pure dense, thin bedded limestone and layers of softer, more massive, argillaceous limestone. Examination of cores reveals that the pure limestone members have frequently been partly dissolved along bedding and joint planes and thus appear as a series of thin, platy beds with partings of calcite or residual red clay. The argillaceious members, on the other hand, have been less dissolved and yield solid cores. Stylolites and small vugs or cavities are rather common throughout the formation, particularly in the pure members.

(d) Spearfish Formation. The Spearfish Formation normally consists of about 350 feet of red silty shale containing conspicuous beds of white gypsum. The principal gypsum bearing member is approximately 100 feet thick, and lies between 100 and 200 feet above the base of the formation. The ridge just to the east of the spillway is capped by the resistant gypsum beds and the contact between the Spearfish and underlying Minnekahta occurs roughly along the centerline of the spillway.

(e) Pleistocene gravel. At an earlier stage in its history, the valley of Cold Brook became choked with gravel as a result of alluviation processes during the glacial epoch. Renewed downcutting was initiated in the post-glacial epoch and much of the gravel within the confines of the valley was removed, however, remnants of this Pleistocene gravel are still present as terraces downstream from the dam.

(f) Alluvium and Talus. Bedrock at the damsite is overlain by 33 feet or less or recent stream gravels, silt, clay, and talus from the valley walls.

3.3. Structure. The geologic structure in the area surrounding the dam is characterized by several slight changes in the rate and direction of dip and variations of from 5 to 35 degrees in dip are encountered. Along the axis, the dip averages 5 to 6 degrees nearly due east essentially parallel to the axis. The dip is more consistent with the regional trend along the site of the spillway, varying from 7.5 to 10 degrees in a south 70 degrees east direction. No wide scale faulting is known to occur within the reservoir area, but occasional faults of slight displacement are encountered along the outcrop of the Minnekahta formation, particularly along the outward facing

escarpment of this formation along the valley walls. The wide variation of lithology of cores obtained in various deep holes indicates the presence of a local unconformity at the contact between the Minnelusa and overlying Opeche Formations. The existence of this unconformity is substantiated by the presence of the brecciated zone near the top of the Minnelusa Formation.

3.4. Ground Water. Prior to construction of the dam a large percentage of the yearly flow of Cold Brook Creek passed through the reservoir area as a subsurface flow. This flow of water was most pronounced in the coarse alluvium existing above the bedrock in the valley bottom. The stream, which maintains a year-round surface flow throughout most of its course, passed underground at a point about three-quarters of a mile upstream from the dam, before the dam was constructed and reissued as a surface flow a short distance downstream from the damsite. The average elevation of the groundwater surface at the damsite prior to excavation and de-watering operations was approximately 3535.0.

IV EXCAVATION

4.1. General. Notice to proceed with work on construction of Cold Brook Dam was issued to the successful bidder, Northwest Engineering Company of Rapid City, South Dakota, on 23 June 1950 and actual work at the project commenced on 10 July 1950. As a matter of convenience, in referring to various aspects of excavation and grouting, the foundation area of the main dam section was arbitrarily divided into three separate sections, namely; the west abutment section, the valley section, and the east abutment section. Excavation of trenches in the foundation, for installation of the impervious cutoff and outlet works conduit, and removal of overhanging ledge rock on the abutments were required. Excavation of the cutoff trench was initiated at the crest elevation of the dam on the west abutment side of the valley and progressed down the abutment to the toe. Excavation of the valley section was carried on concurrently with the west abutment excavation. Design plans stipulated that all excavation within the cutoff trench was to extend to a depth of five feet into sound, unweathered bedrock.

4.2. Right Abutment Section. Overburden on the right or west abutment of the damsite consisted of loose talus composed of blocks of limestone and sandstone imbedded in a matrix of weathered red shale and clay of the Opeche Formation. Excavation of the talus overburden disclosed that the underlying Opeche Formation consisted of alternate zones of soft, red, sandy shale and hard, highly jointed red sandstone and limestone ledges. Light blasting was used to loosen the upper five feet of the Opeche Formation and to deepen the cutoff trench to the plan grade. The vertical joints so prevalent in the sandstone ledges tended to cause breakage to occur along these joints and resulted in a "stair step" profile characterized by slight vertical changes in grade where these joints intersected the profile.

After excavation to plan grade was accomplished, it was noticed that the shale beds were deteriorating rapidly due to the influence of moisture and

weathering. It was decided that no measures would be taken to prevent this weathering until just prior to the placement of the core fill material when all large weathered blocks would be removed.

4.3. Valley Section. Ground water was first encountered during the valley cutoff trench excavation on 6 September 1950, between stations 3+25 and 4+50 at elevation 3534 or approximately 16 feet below the original ground surface. Initial attempts to dewater the area using three specially designed well points proved unsuccessful since the presence of coarse gravel in the alluvium prevented the well points from being jetted down to bedrock. An examination of the ground water characteristics indicated that most of the water was entering the cutoff trench through a very pervious gravel zone which existed immediately above the bedrock.

The plan of dewatering which was finally adopted consisted of over-excavating the cutoff trench along the upstream and downstream limits of the trench a sufficient depth to provide for collector ditches. Since the general dip of the bedrock is toward the east or left abutment, the water flowed by gravity along the collector ditches to the east end of the cutoff trench where a sump was excavated to collect the water. During grouting operations, the bottom of the trench was maintained in a relatively dry condition by constructing sand bag dikes along the bottom of, and parallel to, the sides of the cutoff trench, thus confining the water in shallow collector ditches along the toes of the upstream and downstream slopes of the cutoff trench.

The collector sump which was excavated approximately 10 feet into bedrock consisted of a perforated 18-inch C.M.P. installed vertically with the annular space between the pipe and the periphery of the sump backfilled with coarse gravel. Two 6-inch pumps were installed with intake hoses extending to the bottom of the sump. Water was collected in a 6-inch header and collecting system that discharged into a temporary ditch which extended from the east side of the valley downstream from the cutoff trench to the original stream bed. One pump provided adequate capacity for efficiently dewatering the area and the other pump was maintained as a standby unit. Discharges varied considerably depending on the phase of construction and surface moisture conditions.

Excavation of the cutoff trench disclosed that the bedrock surface throughout the portion of the valley section between stations 3+90 and 7+00 was composed of dense, highly competent limestone. The contract plans and specifications stipulated, however, that all portions of the cutoff trench were to be excavated a minimum of five feet into bedrock. After considerable deliberation, it was decided that excavation of the cutoff trench to a depth of five feet below the top of the limestone bedrock in the above mentioned section would entail an unnecessary expense, without attaining any additional benefits. Therefore, the contractor was directed not to excavate to plan grade in this area.

Due to the eastward dip of the bedrock, the limestone horizon was overlain by a wedge of soft, sandy shale in the section of the cutoff trench between stations 2+20 and 3+90. This shale zone becomes progressively

thicker toward the east and grades laterally into a soft, crumbly red to yellow sandstone near the toe of the east abutment. This shale and sandstone area deteriorated rapidly, due to surface runoff and frequent flooding from ground water during temporary suspension of dewatering operations, to such an extent that grouting of the area, using three foot nipples, was virtually impossible. After a few unsuccessful attempts to grout holes in the area using conventional three-foot long nipples, packers were set at five foot depths and grouting was completed. Upon final completion of grouting, the upper five feet of soft deteriorated shale and sandstone was carefully excavated with draglines and scraper, and the area immediately backfilled with impervious clay.

4.4. Left Abutment Section. No unusual problems were encountered in excavating the left or east abutment section of the cutoff trench. The original slope on this abutment was quite steep, being approximately 1 on 1. A 3/4-yard capacity shovel working from berms excavated at several levels by bulldozers was used to strip the loose talus from the slope. The escarpment of Minnekahta limestone forming the abutment rim was blasted and sloped back to the required limits, and the broken material moved down the slope by gravity to the point where the shovel could remove the material and place it in dump trucks for disposal in the spoils area. Final excavation to plan depth was accomplished by light blasting. Foundation rock in this abutment is similar to that found in the right abutment but contains a larger number of sandstone ledges. Breakage of rock occurred along bedding planes and vertical joints.

4.5. Spillway Excavation. The spillway channel was excavated in a natural divide forming the contact between the Minnekahta limestone and the Spearfish shale. Due to the regional dip to the east, the foundation material on the west side of the spillway is Minnekahta limestone and the foundation material throughout most of the spillway is firm Spearfish shale. The limestone forming the west slope of the spillway channel was badly laminated and somewhat disintegrated. Several large cavities were encountered and these were backfilled with concrete. Since discharges through the spillway will be limited to the passage of a spillway flood of infrequent occurrence, no provisions were made for lining the excavated channel except at the crest section. The crest section, which is 58 feet in length, is protected by a two-foot thick concrete slab. A concrete cutoff wall on the upstream end of the concrete slab extends six feet into bedrock.

4.6. Conduit and Stilling Basin Excavation. Design of the channel slab, floor, and walls of the stilling basin was predicated on founding the concrete slabs and wall footings on firm unweathered rock. Some doubt as to the depth of firm rock beneath the conduit outlet arose as a result of excavating for the extreme downstream monolith on the conduit where it was deemed necessary to excavate approximately four feet below the plan grade to obtain firm material. Had this same situation prevailed in the area beneath the conduit outlet walls and apron, it would have been necessary to modify design criteria. Consequently, it was decided to excavate several test pits in the area to ascertain the depth to firm material.

The test pits were excavated by means of a ripper and dragline and consisted of two trenches approximately at right angles to the centerline of the channel at conduit stations 10+34 and 11+10, respectively. At station 10+34 the red sandy shale of the Opeche Formation was encountered at elevation 3530.5 at a point six feet left of centerline. The elevation of the shale at station 11+10 was approximately 3528.3 at a point 15 feet left of the channel centerline. Since these elevations were approximately one foot below plan grade at the stations and locations mentioned and because of the eastward dip of the formation, it became necessary to backfill low areas on the east side of the centerline with concrete in order to bring the structure up to plan grade. The entire area of the stilling basin, the headwall, and lower downstream monoliths of the conduit are all founded at or near the contact between the Opeche shale and the underlying Minnelusa limestone. Differential erosion, lensing and interfingering of these two formations at or near the plan grade of the conduit and stilling basin structures resulted in a foundation of varying and erratic lithology consisting partially of dense limestone and partially of shale, as was the situation in the cutoff trench. In the shale areas of the conduit trench, excavation to final grade beneath successive monoliths was deferred until the invert for the adjacent upstream monolith had been formed and poured in order to minimize the possibility of weathering and deterioration of the shale.

V FOUNDATION TREATMENT

5.1. General. The results of the core borings made across the axis of the cutoff trench during the fall and winter of 1949-50 disclosed that the limestone and shale comprising the upper part of the Minnelusa Formation and the foundation rock beneath the Cold Brook Dam was highly fractured and brecciated indicating the desirability of installing a grout curtain beneath the cutoff trench. During the course of a conference held in the Division Office at Omaha, Nebraska attended by Mr. E. B. Burwell of the Chief of Engineers office and representatives of the Division and District offices, the problem of grouting and foundation treatment was fully discussed. After reviewing the geology of the damsite and examining representative cores, Mr. Burwell stated that a single line of grout holes across the axis of the cutoff trench and extending up the abutments to the crest elevation of the dam would be desirable. An initial spacing of ten feet was decided upon and it was agreed to extend the holes in the valley bottom to the approximate mid-point of the red to orange fine-grained sandstone underlying the brecciated limestone. It was also agreed to use the "rule of thumb" method of one pound pressure for each foot depth and to perform stage grouting from the surface downward. Plate No. 3 shows the grout curtain details.

5.2. Equipment and Procedure. Grouting was accomplished with the following equipment: two air-driven, double acting sludge-pumps, capable of producing 100 p.s.i. pressure; two mixing tanks containing air-driven agitators and two pumping tanks also containing air-driven agitators and fed by gravity from the mixing tanks. The pumps possessed 3-inch high-pressure rubber hose intakes to the pumping tanks and 2-inch discharge hoses leading to the grout head. A 1-1/2 inch hose was used as a return line from grout head to the pumping tank.

The grout head consisted of a combination of 2-inch pipe fittings and iron valves fitted together in the form of a tee, with each arm of the tee containing a valve. The upright portion contained two nipples connected to a union with each nipple possessing a valve. The discharge hose was connected to one arm of the tee and the return hose was connected to the opposite arm. The upright portion was screwed onto the threaded nipple which was grouted into bedrock.

Grouting was always commenced with the valves on the feed and return lines open and the top valve in the upright closed. This allowed grout to circulate freely in the lines with none being injected in the hole. The closed valve on the upright was then opened slowly at a signal from the inspector, until the gage, also located in the upright, showed the desired pressure. Generally, this was the only valve used during the grouting operations. However, various combinations of partially opened valves were used on a few occasions to regulate pressure, such as partially closing the valve on the return arm of the tee to raise the pumping pressure.

When a given stage of grouting was completed on a hole, the top valve was closed to prevent rising pressure. Then, if any back pressure had been obtained, the bottom valve was closed and this portion of the grout head was left connected to the nipple as long as it was desired to maintain pressure.

The air-driven equipment on one grout machine was powered by a 315 c.f.m. gasoline-powered compressor and the other by a battery of two 210 c.f.m. diesel-powered compressors. These compressors were also used to actuate the rotary drills and water pumps during preliminary drilling and pressure testing. Mixing water was gravity-fed from storage tanks to the mixing tanks and cement was dumped into the mixing tanks by hand from paper bags.

The packer most generally used was a multiple-seal mechanical type packer having four 2-inch long rubber seals on the bottom of 1-1/2 inch double rods. The top of the inside rod was threaded and fitted with a wing nut so that the inner rod could be forced up through the outer rod, after the packer was inserted to the proper depth, thus expanding the rubber seals. This packer proved very effective except in a few instances where the soft material encountered had allowed the hole to whip out either from drill water erosion or rod vibration. In these instances a pneumatic single-seal packer was used. Drills used were two Boyles Bros., Jr. 01, air-driven, rotary four feed ratio diamond drills, using "E" rods and 1-7/16 inch diamond plug bits. Bortz and Congo stones were both used on the job with equal success. Bits having two waterways performed better than bits with single passage waterways.

5.3. <u>Grouting Operations</u>. Preliminary drilling was commenced on 12 October 1950 and three holes Nos. 18, 19 and 20 (the uppermost holes on the right abutment) were drilled to depths varying from 15 to 20 feet deep. Water losses occurred on each of the three holes during the drilling operations. These three holes were on 10 foot centers and the original 145 foot deep exploration hole No. 1 was situated approximately 2.5 feet from hole No. 19. Washing of the holes in the manner described in the specifications had

not been very successful due to loss of water through vertical joints which intersected the surface. The log of hole No. 1 indicated that no water had been lost during drilling, and the hole had been dry previous to the initial drilling of grout holes 18, 19 and 20.

Discussions on 19 October 1950 between a representative of the Chief of Engineers office and representatives of the Division and District offices revealed the necessity for grouting exploratory hole No. 1 prior to making any attempt to carry out the specified procedure of grouting holes 18, 19 and 20. This was done on the afternoon of 19 October, and with the pressures attained, holes 18 and 19 (the adjacent holes) were partially grouted due to communication between these holes and hole No. 1. Grout also issued to the surface in several places adjacent to the grouting operations. After injecting 45 sacks of cement in hole No. 1 without attaining refusal, the grouting of this hole was stopped and holes 18 and 20 were grouted with a maximum pressure of 5 p.s.i. attained before surface leakage forced curtailment of grouting. A total of 72 bags of cement were injected in these two holes before the initial grouting was curtailed because of surface leakage.

The above experiences and other details developed through discussions and observations at the site revealed that certain procedures and changes would be advantageous. These procedures and changes were considered primarily to insure the integrity of the dam foundation. It was considered that below the level of the conservation pool, or of the lowest normal intake to the conduit, water could conceivably seep through minute fissures in the limestone foundation beneath the valley section and initiate piping of the fill if a positive grouting of the upper few feet of the limestone was not attained. Because grouting of this limestone was scheduled prior to the placing of the impervious core, some concern was felt that it would not be possible to grout at sufficiently high pressures to assure a tight seal in the critical upper few feet of the bedrock.

A proposal was therefore made to excavate a trapezoidal shaped trench, approximately 7 feet wide at the top, 3 feet wide at the bottom, and 5 feet in depth from the bottom of the cutoff trench. This trench would extend approximately 700 feet along that portion of the cutoff trench below the elevation of the conservation pool. It was then proposed to backfill this trench using class B concrete, with grout pipe collars spaced 10 feet on center set in place before making the concrete pour. The weight and structural strength of this concrete would permit grouting of the underlying rock fissures in an effective manner, and the concrete surface would be of sufficient width to permit making an effective seal at the contact between the impervious core and the concrete.

Since representatives of the Division office also expressed concern that the depth of the grout holes as specified, which was approximately 30 feet deep, would not provide an adequate and effective curtain across the valley, a conference was held at Fort Randall, South Dakota on 31 October 1950 to consider the above proposal and other problems of grouting. The conference was attended by representatives of the Office, Chief of Engineers; Missouri River Division; and the Fort Peck District. The conferees determined that

the construction of a concrete filled trench below the existing cutoff trench was unnecessary and that an adequate grout job could be attained by stage grouting along the entire cutoff trench using the split-spacing method of grouting in which primary holes spaced on 40 foot centers would be grouted first, then secondary holes on 20 foot centers and finally closing in on ten foot centers. The results of grouting on ten foot centers would then be used in arriving at a conclusion as to the necessity of going to a closer spacing. It was also decided to extend the grout holes in the valley section below the conservation pool level to a minimum depth of 40 feet.

The above method of grouting was adhered to very closely in grouting the right abutment and a portion of the valley section, although when a suitable packer was devised, holes were often drilled to final depth and grouted in stages from the bottom up, except in cases where total loss of drill water made further drilling impossible.

The left abutment, possessing a very steep slope, was treated in a different manner. Holes 92 to 110 ranged in depth from 54 to 74 feet with the exception of hole 96, which was drilled to a depth of 105 feet in order to test the tightness of the deep strata beneath the left abutment. All holes on the left abutment were drilled and grouted progressively from the lower portion of the abutment to the top. Since corresponding depths in adjacent holes did not always penetrate the same bedding planes or strata (due to the eastward dip of the strata and the steep 1 on 1 slope of the abutment), the system of treating holes in the split-spacing manner heretofore mentioned was abandoned.

The upper zone of the abutment in which holes 92 through 107 were drilled consisted of blocky, highly jointed, shaley sandstones of the Opeche Formation and holes 108, 109 and 110 at the extreme top of the left abutment penetrated the laminated and fractured limestone of the Minnekahta Formation, both formations which would not withstand even moderate pressures. These holes were therefore drilled to a 21 foot depth with a 2-inch plug bit and were grouted to refusal under approximately 8 p.s.i. pressure. After water testing to assure tightness of this 0 to 21 foot zone, a 21 foot length of 1-1/2 inch galvanized pipe was grouted in each hole. This permitted much higher pressures to be used in grouting the lower zones of these holes and minimized the possibility of rupturing the upper zone which had been grouted under 8 pounds pressure. This method was also used in holes 20 and 23 on the right abutment, since experimental grouting had fractured the 0 to 15 foot zone in these holes.

After holes 18 to 110 inclusive, had been grouted to completion, locations 5 feet in advance of holes 28, 29, 31, 33, 35, 36, 37, 42, 52, 57, 58, 59, 70, 71, 73 and 74 were deemed critical areas in the upper zone of the foundation and holes 15 feet in depth were drilled and tested at these locations. These holes were designated by the capital letter "A", i.e. 28A. Only three of these holes could be induced to take grout under pressures previously used in grouting adjacent holes. Hole 74A readily took 7 c.f. of grout having a water-cement ratio of 6 and then refused abruptly, indicating the presence of a small isolated cavity in the limestone. Hole 52A surface-

leaked on grouting and grout issued from the face of the conduit trench which crossed the cutoff trench near 52A. Refusal was finally attained on this hole after 23 c.f. of grout had been injected in a later grouting of the hole. Hole 36A required 75 c.f. of grout before refusal was attained.

Primary holes, as would be expected, generally required the largest amount of grout, the greatest grout consumption in any one individual hole occurring at hole No. 44 which required a total of 475.5 bags of cement for a 40 foot depth or an average of 11.9 bags per foot of hole. Further analysis of the grout consumption in this hole shows that 307 bags of the above total were injected between the 30 and 40 foot zone. Adjacent holes 41, 42, 43 and 46 all required large grout quantities before refusal was attained. A total of 1,632 bags of cement were injected in holes 41 through 46 inclusive, and 1,343 bags of the total were injected between the 30 and 40 foot zone of the foundation. Examination of the geologic profile (Plate No. 3) indicates that the zone where the excessive grout was required occurred at or near the contact between the relatively impervious orange sandstone and underlying limestone. A similar situation occurred at hole Nos. 56, 58, 60, 63 and 66 where 938 bags of cement were injected in the 30 to 40 foot zone.

An examination of the outcropping Minnelusa formation located one mile upstream from the dam disclosed that a well defined bedding plane exists at the contact between the sandstone and lower limestone, the same zone which required the large volume of grout in the above mentioned holes. In places, this bedding plane at the contact has been leached out and many small pockets and cavities are present. It is believed that the same conditions prevailed beneath the dam and these cavities were the primary reason why such a large volume of grout was required in the 30 to 40 foot zone.

One of the major difficulties encountered during the grouting phase of the foundation work was the excessive surface leakage of grout. This condition was particularly prevalent on the west abutment, because of the fact that the dip of the formations was toward the east abutment at a lesser angle than the excavated slope. Consequently, grout injected in the first stage grouting tended to move freely along bedding planes and down the dip of the formations to come out on the surface at a lower elevation. Repeated grouting of these holes using a water-cement ratio of 0.6 failed to seal all surface leakage and it was necessary to introduce a grout mix having a water-cement ratio of 0.4 into the top of several holes by pouring the grout from buckets and periodically applying 15 pounds air pressure to facilitate movement of the heavy grout mixture into zones of excessive leakage. This method proved very effective in sealing major leaks and enabled the grouting crew to proceed with second stage drilling and grouting on these holes. The excessive surface leakage on the right or west abutment led to the decision to revert to the use of 21-foot pipes in the holes on the left abutment as described previously in this report.

It was found expedient where surface leakage occurred on first stage grouting in the valley section to caulk all surface fissures or cracks as tightly as possible and allow the heavy grout to set in the hole and fissures. The hardened grout in the hole would then be re-drilled. The

surface then usually proved tight after one grouting operation, whereas had the hole been washed before the grout had fully set, the grout would have flowed back into the drill hole, or would have been thinned or washed from the fissures by wash water.

Much of the grouting was accomplished during freezing weather and difficulty was encountered in several holes because water tended to freeze in surface cracks and give an erroneous impression of a tight foundation on pressure testing of the 0-15 foot zone prior to commencing first stage grouting. In cases where pressure testing indicated a tight hole, the hole was deepened to the next stage without grouting the upper zone and in several instances attempts to grout these holes from the surface to the second stage depth were ineffective because of profuse surface leakage which occurred through fissures which had previously appeared tight on pressure testing.

5.4. Impervious Core. After completion of grouting operations, all loose and disintegrated material which could not be effectively rolled in the fill was removed from the cutoff trench and backfilling of the trench with impervious material was initiated. A sand and gravel filter consisting of 12 inches of sand and 18 inches of graded gravel was placed on the downstream slope of the cutoff trench and extended from the base of the cutoff to the stripped ground surface along the entire length of the cutoff.

In order to provide for drainage and diversion of water during backfilling operations, a French drain consisting of a perforated 10-inch metal pipe embedded in pervious gravel was installed along the upstream toe of the cutoff trench between stations 1+60 and 4+75. Drainage water was pumped from the east end of the cutoff trench from the original sump which had been excavated prior to grouting. A 10-inch riser pipe was installed in this sump and the riser pipe and attached suction hose leading to the pump were extended vertically as backfilling progressed. Two-inch riser pipes were welded to the 10-inch horizontal drain pipe at 75 foot centers and extended upward through the fill to an elevation approximately five feet above the invert grade of the conduit. When the fill reached the top of these 2-inch riser pipes, the pumping was discontinued and a grout mixture containing fly ash was injected in each of the riser pipes until the entire system was sealed. A total of 430 bags of cement and 100 bags of fly ash were required to seal up the system.

VI OBSERVATIONS AND CONCLUSIONS

6.1. General. Control of underseepage is usually the prime consideration in the foundation treatment of an earth fill dam. Since the depth of alluvial materials beneath Cold Brook Dam was not excessive, the control of underseepage entailed the construction of an impervious earth cutoff to bedrock. Supplementary investigations, however, revealed that foundation bedrock on which the cutoff would be founded consisted of brecciated and fractured limestone and blocky shales, siltstones and sandstones which gave every indication of being highly pervious and indicated the need for a cutoff curtain of grout.

An analysis of the grouting operations at Cold Brook Dam discloses that 4666.5 feet of holes were drilled in the foundation and 6786.7 bags of cement were injected which is an average of 1.45 bags of cement per foot of hole drilled. This relatively high quantity of grout does not tell the full story, for as described elsewhere in this report, a large percentage of the grout was consumed in localized zones of the foundation. The large consumption of grout in local zones, many of them close to the surface, clearly demonstrates that the entire grouting program was justified.

6.2. Effectiveness of the Foundation Treatment. Upon completion of the grout curtain, water levels upstream from the curtain zone began rising and seepage of water was noticed in the upstream portion of the conduit trench. Upon completion of the backfilling operations of the cutoff trench to the original ground levels, de-watering operations were temporarily discontinued and water quickly rose in the excavated borrow areas upstream from the cutoff trench to such an extent that it again became necessary to re-activate the pumps in order to unwater the lower pervious zone of the borrow area. A noticeable increase occurred in volume of seepage through the entire working season. Since there was no surface flow in Cold Brook Creek, all water which was ponded or discharged was derived from underground sources.

Throughout the period of embankment construction a plentiful supply of water for compaction was obtained from a temporary drainage ditch excavated from the upstream side of the fill. In addition, a minimum of 0.5 c.f.s. of water was diverted through the fill to supply Larvie Lake, a small conservation and recreation pool situated about 1-1/2 miles downstream from Cold Brook Dam. A slow but steady rise of water levels has taken place in the conservation pool area of Cold Brook Dam since completion of embankment operations.

6.3. Depletion of Downstream Water Wells. One other aspect pointing to the effectiveness of the grout curtain and cutoff at Cold Brook Dam has been the problem of the depletion and drying up of water wells of local landowners living downstream from Cold Brook Dam. This problem was first brought to the attention of the District Engineer on 16 May 1951 when three residents of the area made verbal complaints to the Resident Engineer that their wells were dry and that the water level was dropping in other wells in the area. This reported date of depletion of wells coincides closely with the date of completion of the grout curtain, which was effected on 2 May 1951.

An investigation of all affected wells was made by the Resident Engineer and the reports of the landowners were substantiated. The investigation revealed that all affected wells were hand dug wells excavated to bedrock and that water supply was obtained through the alluvium. Periodic checks of water levels were made on all wells up until the completion of the dam. It has been noted that the wells were most severely depleted during those periods of construction when heavy demands were made on the available supply of ground water for fill compaction. During these periods no water was diverted to the downstream portion of Cold Brook. In winter months and other off-season periods of construction, slight increases in ground-water levels were apparent. During these periods, it was necessary to divert water through the conduit and into the stream bed of Cold Brook Creek.

After the closure was made on the invert section of the intake, no water was diverted through the conduit, and immediately several complaints were made to the Resident Engineer. Since the lowest intake ports are located at elevation 3585.0, no appreciable quantity of water can be diverted, except for minor amounts through a control valve at elevation 3548.0 until such time as the conservation pool reaches the elevation of the intake ports, and as a consequence, little or no water is available to replenish the supply to the downstream wells. The problem of depletion of water in these wells and the responsibility of the government toward the well owners has been fully treated and recommendations have been set forth in a series of report memoranda which were forwarded to higher authority.

The conclusions to be drawn from the depletion of wells is that the construction of the grout curtain and cutoff core has effectively cut off the natural flow of underground water beneath the dam. It is apparent also that this condition will continue until such times as the quantity of water upstream from the dam is increased through run-off to a point where sufficient water can be diverted through the conduit to replenish the normal supply downstream.

6.4. Possible Need for Additional Grouting. The left abutment rim of the reservoir is capped, as previously indicated in this report, by 45 to 50 feet of dense to slabby limestone constituting the Minnekahta formation. In the preconstruction period, this rim existed as a steep escarpment at the reservoir site and it was considered the presence of the escarpment after completion of the dam would be a potential hazard to people using the area for recreation purposes. Furthermore, an examination of the rim disclosed certain evidences of the presence of a fissure running parallel with the rim and located about 15 to 25 feet back from the face of the escarpment for a distance of several hundred feet upstream from the axis. The presence of this fissure and the possibility of a future slide in the area due to the fissure together with attendant potential hazards to recreation users resulted in a determination to slope the rim back to a safe slope of 1 on 1 and to use the excavated material for riprap and spalls.

The contractor began sloping operations in this area prior to completion of the fill, but because of difficulties in working the face and obtaining acceptable riprap, he asked for and received permission to obtain riprap from another source. This permission was granted with the provision that the contractor complete the required sloping in the area after completion of the fill or before final acceptance.

Back sloping of this rim area necessitated considerable blasting and resulted in considerable excavation in excess of the originally stipulated plan of sloping back on a 1 on 1 slope. Upon completion of this operation, it was noted that much of the limestone was highly fractured and laminated. The grout curtain as shown on the profile, Plate No. 3 shows that holes 108, 109 and 110 penetrate portions of the limestone cap on the left abutment. Since the maximum reservoir water surface elevation during project flood flows will be at elevation 3667.8, which would bring the water level well up into this limestone horizon, there is some possibility of a path of flow

developing through the limestone, around the limits of the existing grout curtain in the left abutment. Such leakage could possibly cause serious erosion of the fill at the contact of the fill and the left abutment of the dam downstream from the grout curtain. For this reason consideration is being given to extending the grout curtain farther into the abutment or else extending a line of grout holes upstream from the axis and parallel to the reservoir rim.

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
18	1-7/16	20.4	0-20.4	101	5.0	12	5:2	0.7:1	1.3:1
		30.0	20.4-30.0	61.5	7.2	11	4:1	1:1	1.5:1
		40.0	30.0-40.0	0	0.0	11	4:1	4:1	4:1
		40.0	Total	162.5	4.1				1.4:1
19	1-7/16	15.0	0-15.0	6	0.4	16	4:1	4:1	4:1
		40.0	15-40.0	0	0.0	8	1:1	1:1	1:1
		40.0	Total	6	0.2				4:1
20(P)	1-7/16	16.0	0-16.0	182	11.4	10	3:2	0.6:1	1.1:1
		44.0	16-44.0	0	0.0	10	0.75:1	0.75:1	0.75:1
		44.0	Total	182	4.1				1.1:1
21(T)	1-7/16	46.0	0-46.0	0	0.0	8	1:1	1:1	1:1
		46.0	Total	0	0.0				1:1
22S	1-7/16	15.2	0-15.2	23	1.6	5	4:1	0.7:1	2.4:1
		45.0	15.2-45	23	0.8	8	6:1	0.75:1	1.7:1
		45.0	Total	46	1.0				2:1
23(T)	1-7/16	15.0	0-15.0	75	5.0	0	4:1	(1) Neat Mortar Approx. 0.3:1	0.9:1
		45.0	15-45.0	0	0.0	8	3:1	3:1	3:1
		45.0	Total	75	1.7				0.9:1
24(P)	1-7/16	35.9	0-20.0	43	2.2	10	4:1	0.7:1	1.9:1
		35.9	20-35.9	2	0.1	15	4:1	4:1	4:1
		45.1	35.9-45.0	0	0.0	15	3:1	3:1	3:1
		45.0	Total	45	1.0				2:1

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FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
25T	1-7/16	15.0	0-15.0	9	0.6	9	3:1	1:1	2.1:1
		30.0	15-30.0	1	0.1	10	4:1	4:1	4:1
		45.0	30-45.0	2	0.1	10	6:1	6:1	6:1
		45.0	Total	12	0.3				3:1
26S	1-7/16	15.0	0-15.0	0	0.0	No grouting required			
		30.0	15-30.0	0.2	0.0	16	4:1	4:1	4:1
		40.0	30-40.0	0	0.0	No grouting required			
		40.0	Total	0.2	0.0				4:1
27T	1-7/16	15.0	0-15.0	7	0.5	8	6:1	0.65:1	2.5:1
		30.0	15-30.0	0	0.0	15	6:1	6:1	6:1
		45.0	30-45.0	0	0.0	No grouting required			
		45.0	Total	7	0.2				2.5:1
28(P)	1-7/16	46.5	0-46.5	1.4	0.0	10	4:1	4:1	4:1
28A	1-7/16	15.0	0-15.0	20.0	1.0	No grouting required			
29(T)	1-7/16	15.0	0-15.0	20.0	1.3	7	4:1	0.7:1	1.3:1
		30.0	15-30.0	15.0	1.0	10	4:1	0.7:1	2.8:1
		48.0	30-48.0	0.0	0.0	10	6:1	6:1	6:1
		48.0	Total	35.0	0.7				1.8:1
29A	1-7/16	15.0				No grouting required			
30(S)	1-7/16	30.0	0-30.0	13.0	0.4	15	4:1	1:1	2.2:1
		33.1	30-33.1	8.0	2.6	15	2:1	2:1	2:1
		50.0	33.1-50.0	0.0	0.0	15	6:1	6:1	6:1
		50.0	Total	21.0	0.4				2.1:1

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
31(T)	1-7/16	15.0	0-15.0	0.0	0.0	10	6:1	6:1	6:1
		30.0	15-30.0	0.5	0.0	15	1:1	1:1	1:1
		40.0	30-40.0	0.0	0.0	15	4:1	4:1	4:1
		52.0	40-52.0	0.5	0.0	15	6:1	6:1	6:1
		52.0	Total	1.0	0.0				1:1
31A	1-7/16	15.0				No grouting required			
32(P)	1-7/16	40.0	0-40	18.0	0.5	18	5:1	0.7:1	3.1:1
		54.0	40-54	0.0	0.0	No grouting required			
		54.0	Total	18.0	0.3				3.1:1
33(T)	1-7/16	15.0	0-15.0	1.0	0.1	10	1:1	1:1	1:1
		30.0	15-30.0	0.2	0.0	15	2:1	2:1	2:1
		55.0	30-55.0	0.0	0.0	No grouting required			
		55.0	Total	1.2	0.0	15			1.2:1
33A	1-7/16	15.0				No grouting required			
34(S)	1-7/16	30.0	0-30.0	1.0	0.0	15	4:1	4:1	4:1
		52.0	30-52.0	0.0	0.0	No grouting required			
		52.0	Total	1.0	0.0				4:1
35(T)	1-7/16	15.0	0-15.0	1.0	0.1	5	4:1	4:1	4:1
		30.0	15-30.0	0.0	0.0	10	5:1	5:1	5:1
		43.0	30-43.0	80.0	6.2	15	6:1	0.6:1	2.8:1
		47.0	43-47.0	0.0	0.0	No grouting required			
		47.0	Total	81.0	1.7				2.8:1
35A	1-7/16	15.0				No grouting required			

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
36(P)	1-7/16	9.0	0-9.0	63.0	7.0	15	4:1	1:1	1.3:1
		30.0	9-30.0	1.0	0.0	15	4:1	4:1	4:1
		40.0	30-40.0	0.0	0.0	No grouting required			
		40.0	Total	64.0	1.6				1.3:1
36A	1-7/16	15.0	0-15.0	75.0	5.0	13	3:1	1:1	1.5:1
37(T)	1-7/16	15.0	0-15.0	19.0	1.3	5	4:1	0.6:1	1.3:1
		40.0	15-40.0	0.0	0.0	No grouting required			
		40.0	Total	19.0	0.5				1.3:1
37A	1-7/16					No grouting required			
38(S)	1-7/16	15.0	0-15.0	32.0	2.1	4	4:1	1:1	1.6:1
		40.0	15-40.0	58.0	2.3	15	5:1	1:1	1.8:1
		40.0	Total	90.0	2.3				1.7:1
39(T)	1-7.16	40.0				No grouting required			
40(P)	1-7/16	40.0	0-40.0	2.3	0.1	15	2:1	2:1	2:1
		40.0	Total	2.3	0.1	15			2:1
41(T)	1-7/16	15.0	0-15.0	0.0	0.0	15	5:1	5:1	5:1
		35.0	15-35.0	59.0	3.0	15	4:1	6:1	2.7:1
		40.0	35-40.0	177.0	35.4	0	2:1	0.6:1	0.8:1
		40.0	Total	236.0	5.9				1.3:1
42(S)	1-7/16	30.0	0-30.0	53.6	1.8	15	2:1	0.7:1	0.9:1
		32.0	30-32.0	162.0	81.0	15	4:1	1:1	1.5:1
		40.0	32-40.0	0.0	0.0	15	No grouting required		
		40.0	Total	215.6	5.4				1.3:1

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
42A	1-7/16	15.0				No grouting required			
43(T)	1-7/16	30.0	0-30.0	13.0	0.4	17	5:1	1:1	2.8:1
		40.0	30-40.0	255.0	25.5	15	6:1	0.6:1	1.1:1
		40.0	Total	268.0	6.7				1.2:1
44(P)	1-7/16	30.8	0-30.8	168.5	5.5	16	4:1	0.6:1	0.8:1
		40.0	30.8-40	307.0	33.4	15	4:1	0.6:1	0.8:1
		40.0	Total	475.5	11.9				1.2:1
45(T)	1-7/16	40.0	0-40.0	2.0	0.1	15	6:1	6:1	6:1
46(S)	1-7/16	15.0	0-15.0	3.0	0.2	15.0	6:1	6:1	6:1
		40.0	15-40.0	442.0	17.1	90.0	5:1	1:1	1:1
		40.0	Total	445.0	11.1	90.0			1.1:1
47(T)	1-7/16	40.0	0-40.0	0.0	0.0	15.0	4:1	4:1	4:1
48(P)	1-7/16	30.0	0-30.0	72.0	2.4	15.0	5:1	0.7:1	1.9:1
		40.0	30-40.0	0.0	0.0	15.0	No grouting required		
		40.0	Total	72.0	1.8				1.9:1
49(T)	1-7/16	30.0	0-30.0	0.5	0.0	15.0	4:1	4:1	4:1
		40.0	30-40.0	0.0	0.0	15.0	No grouting required		
		40.0	Total	0.5	0.0				4:1
50(S)	1-7/16	40.0	0-40.0	0.0	0.0	15.0	No grouting required		
51(T)	1-7/16	15.0	0-15.0	2.0	0.1	15.0	4:1	4:1	4:1
		40.0	15-40.0	0.0	0.0	15.0	No grouting required		
		40.0	Total	2.0	0.1				4:1

TABLE I

FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
52(P)	1-7/16	15.0	0-15.0	13.0	1.0	15.0	6:1	3:1	5.3:1
		40.0	15-40.0	0.0	0.0	15.0	6:1	6:1	6:1
		40.0	Total	13.0	0.3				5.3:1
52A	1-7/16	15.0	0-15.0	23.0	1.5	14.0	6:1	1:1	1.9:1
53(T)	1-7/16	40.0	30-40.0	0.0	0.0	40.0	6:1	6:1	6:1
		40.0	0-30.0	15.0	0.5	20.0	6:1	0.6:1	2.6:1
		40.0	Total	15.0	0.4				2.6:1
54(S)	1-7/16	40.0	30-40.0	0.0	0.0	15.0	6:1	6:1	6:1
		40.0	0-30.0	22.0	0.7	15.0	6:1	6:1	1.6:1
		40.0	Total	22.0	0.6				1.6:1
55(T)	1-7/16	40.0	0-40.0	2.0	0.1	15.0	6:1	6:1	6:1
56(P)	1-7/16	15.0	0-15.0	3.3	0.2	15.0	6:1	6:1	6:1
		30.0	15-30.0	0.4	0.0	15.0	6:1	6:1	6:1
		35.2	30-35.2	290.0	55.8	20.0	6:1	0.6:1	0.9:1
		40.0	35.2-40.0	0.0	0.0	15.0	No grouting required		
		40.0	Total	293.7	7.3				1:1
56A	1-7/16	15.0	0-15.0	0.0	0.0		No grouting required		
57(T)	1-7/16	40.0	30-40.0	3.0	0.3	40.0	6:1	6:1	6:1
		40.0	0-30.0	1.0	0.0	20.0	6:1	6:1	6:1
		40.0	Total	4.0	0.1				6:1
57A	1-7/16	15.0					No grouting required		
58(S)	1-7/16	40.0	32-40.0	250.0	31.3	20.0	6:1	0.6:1	0.8:1
		40.0	0-32.0	51.0	1.6	15.0	1:1	0.7:1	0.9:1
		40.0	Total	301.0	7.5				0.8:1

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
58A	1-7/16	15.0	0.15.0				No grouting required		
59(T)	1-7/16	15.0	0-15.0	51.0	3.4	5.0	6:1	0.6:1	2.3:1
		40.0	15-40.0	20.0	0.8	15.0	6:1	3:1	4.3:1
		40.0	Total	71.0	1.8	15.0			2.9:1
59A	1-7/16	15.0					No grouting required		
60(P)	1-7/16	15.0	0-15.0	3.7	0.2	15.0	6:1	6:1	6:1
		30.0	15-30.0	0.4	0.0	15.0	6:1	6:1	6:1
		33.0	30-33.0	195.0	65.0	15.0	1:1	1.5:1	1.1:1
		40.0	33-40.0	0.0	0.0	15.0	No grouting required		
		40.0	Total	199.0	5.0	15.0			1.2:1
61(T)	1-7/16	40.0	0-40.0	0.0	0.0	15.0	6:1	6:1	6:1
62(S)	1-7/16	15.0	0-15.0	45.0	3.0	5.0	6:1	0.6:1	1.7:1
		40.0	15-30.0	0.0	0.0	15.0	6:1	6:1	6:1
		40.0	30-40.0	3.0	0.3	15.0	6:1	6:1	6:1
		40.0	Total	48.0	1.2				1.8:1
63(T)	1-7/16	40.0	30-40.0	92.0	9.2	28.0	6:1	1.5:1	3.8:1
		40.0	0-30.0	0.0	0.0	15.0	6:1	6:1	6:1
		40.0	Total	92.0	2.3				3.8:1
64(P)	1-7/16	15.0	0-15.0	3.2	0.2	15.0	6:1	6:1	6:1
		40.0	15-40.0	7.2	0.3	15.0	6:1	5:1	5.7:1
		40.0	Total	10.4	0.3				5.8:1
65(T)	1-7/16	40.0	30-40.0	0.0	0.0	32.0	6:1	6:1	6:1
		40.0	0-30.0	9.0	0.3	15.0	6:1	1:1	3.7:1
		40.0	Total	9.0	0.2				3.7:1

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
66(S)	1-7/16	15.0	0-15.0	26.0	1.7	?	6:1	Neat Mortar	1:1
		40.0	32-40.0	111.0	14.0	30.0	5:1	0.75:1	2.5:1
		40.0	15-32.0	0.0	0.0	15.0	6:1	6:1	6:1
		40.0	Total	137.0	3.4				2.2:1
67(T)	1-7/16	40.0	0-40.0	2.0	0.1	15.0	6:1	6:1	6:1
68(P)	1-7/16	15.0	0-15.0	0.4	0.0	15.0	6:1	6:1	6:1
		40.0	15-40.0	0.0	0.0	15.0	No grouting required		
		40.0	Total	0.4	0.0				6:1
69(T)	1-7/16	40.0	0-40.0	1.0	0.0	15.0	6:1	6:1	6:1
70(S)	1-7/16	8.4	0-8.4	58.0	6.9	15.0	4:1	1:1	1.4:1
		15.0	8.4-15.0	97.0	14.7	15.0	4:1	1:1	1.4:1
		40.0	15-40.0	77.0	3.1	15.0	6:1	1:1	2.6:1
		40.0	Total	232.0	5.8	15.0			1.8:1
70A	1-7/16	15.0					No grouting required		
71(T)	1-7/16	40.0	31-40.0	36.0	4.0	25.0	6:1	2:1	3.4:1
		40.0	0-31.0	0.0	0.0	15.0	6:1	6:1	6:1
		40.0	Total	36.0	0.9				3.4:1
71A	1-7/16	15.0					No grouting required		
72(P)	1-7/16	10.5	0-10.5	59.0	5.6	15.0	6:1	1:1	1.3:1
		35.1	10.5-35.1	3.0	0.1	15.0	5:1	5:1	5:1
		40.0	35.1-40.0	0.0	0.0	15.0	6:1	6:1	6:1
		40.0	Total	62.0	1.6				1.5:1

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
73(T)	1-7/16	40.0	0-40.0	1.0	0.0	15.0	6:1	6:1	6:1
73A	1-7/16	15.0					No grouting required		
74(S)	1-7/16	20.0	10-20.0	72.0	7.2	20.0	6:1	2:1	2.8:1
		20.0	0-10.0	0.0	0.0	8.0	2:1	2:1	2:1
		40.0	20-40.0	5.0	0.3	15.0	6:1	6:1	6:1
		40.0	Total	77.0	1.9	15.0			3:1
74A 1	1-7/16	15.0	0-15.0	1.0	0.1	40.0	6:1	6:1	6:1
75(T)	1-7/16	40.0	0-40.0	0.5	0.0	15.0	6:1	6:1	6:1
76(P)	1-7/16	30.0	0-30.0	16.0	0.5	? (2)	6:1	Neat Mortar 0.3:1	0.9:1
		40.0	0-40.0	0.0	0.0	15.0	No grouting required		
		40.0	Total	16.0	0.4				0.9:1
77(T)	1-7/16	40.0	6-40.0	2.0	0.1	15.0	6:1	6:1	6:1
		40.0	0-6.0	No grouting attempted					
78(S)	1-7/16	40.0	20-40.2	0.0	0.0	25.0	6:1	6:1	6:1
		40.0	10-20.0	31.0	3.1	20.0	6:1	1.5:1	4.1:1
		40.0	0-10.0	26.0	2.6	0.0	6:1	0.6:1	1.4:1
		40.0	Total	57.0	1.4				2.9:1
79(T)	1-7/16	40.0	5-40.0	0.0	0.0	15.0	6:1	6:1	6:1
		40.0	0-5.0				No grouting attempted		
80(P)	1-7/16	17.5	0-17.5	121.0(3)	6.9	15.0	4:1	0.7:1	1.9:1
		40.0	0-20.0	233.0(3)	11.7	8.0	6:1	Neat Mortar	1:1
		Recap	0-20.0	354.0	17.7				1.3:1
		40.0	20-40.0	0.0	0.0	20.0	6:1	6:1	6:1
		40.0	Total	354.0	8.9				1.3:1

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
81(T)	1-7/16	40.0	5-40.0	0.0	0.0	15.0	6:1	6:1	6:1
82(S)	1-7/16	40.0	5-40.0	4.0	0.1	15.0	6:1	6:1	6:1
		40.0	0-5.0	11.0	2.2	0.0	2:1	0.6:1	1.1:1
		40.0	Total	15.0	0.4				2.4:1
83(T)	1-7/16	40.0	5-40.0	31.0	0.9	15.0	6:1	4:1	5.2:1
		40.0	0-5.0				No grouting attempted		
84(P)	1-7/16	30.0	0-30.0 (4)	19.0	0.6	0.0	4:1	0.6:1	0.8:1
		40.0	30-40.0	0.0	0.0	25.0	6:1	6:1	6:1
		40.0	20-30.0 (4)	100.0	10.0	15.0	6:1	0.6:1	1.9:1
		40.0	0-20.0	59.0	3.0	0.0	2:1	0.6:1	0.8:1
		40.0	Total	178.0	4.5				1.2:1
85(T)	1-7/16	40.0	10-40.0	1.0	0.0	15.0	4:1	4:1	4:1
		40.0	0-10.0	11.0	1.1	5.0	0.6:1	0.6:1	0.6:1
		40.0	Total	12.0	0.3				1:1
86(S)	1-7/16	40.0	21-40.0	234.0	12.3	27.0	6:1	0.6:1	1.5:1
		40.0	10-21.0	38.0	3.4	24.0	3:1	1:1	2.3:1
		40.0	5-10.0	0.0	0.0	15.0	6:1	6:1	6:1
		40.0	0-5.0	12.0	2.4	0.0	2:1	0.6:1	1.5:1
		40.0	Total	284.0	7.1				1.6:1
87(T)	1-7/16	40.0	5-40.0	0.0	0.0	15.0	6:1	6:1	6:1
		40.0	0-5.0				No grouting attempted		
88(P)	1-7/16	15.0	0-15.0	69.0	4.6	0.0	4:1	0.6:1	0.9:1
		40.0	15-40.0	0.0	0.0	40.0	6:1	6:1	6:1
		40.0	Total	69.0	1.7				0.9:1

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
89(T)	1-7/16	30.0	0-30.0	13.0	0.4	5.0	2:1	0.6:1	1.1:1
		46.0	30-46.0	0.0	0.0	20.0	4:1	4:1	4:1
		46.0	Total	13.0	0.3				1.1:1
90(S)	1-7/16	51.0	0-51.0			Hole tight, no grouting required			
91(T)	1-7/16	37.0	0-37.0	9.0	0.2	15.0	4:1	1:1	1:1
		54.0	37-54.0	0.0	0.0		No grouting required		
		54.0	Total	9.0	0.2				1:1
92 (5)	1-7/16	15.0	0-15.0	7.0	0.5	15.0	6:1	3.2:1	3.2:1
		72.0	15-72.0	1.0	0.0	15.0	6:1	6:1	6:1
		72.0	Total	8.0	0.1				3.6:1
93	1-7/16	60.0	0-60.0	21.0	0.4	15.0	6:1	4:1	1.9:1
94	1-7/16	62.0	0-62.0	1.0	0.0	15.0	6:1	6:1	6:1
95	2"	20.2	0-20.2	54.0	2.7	20.0	6:1	1:1	1.4:1
	1-7/16	66.0	20.2-66.0	1.0	0.0	15.0	6:1	6:1	6:1
		66.0	Total	55.0	0.8				1.5:1
96	2"	20.7	0-20.7	0.0	0.0		No grouting required		
	1-7/16	105.0	20.7-105.0	0.0	0.0	20.0	6:1	6:1	6:1
		105.0	Total	0.0	0.0				6:1
97	2"	21.2	0-21.2	2.0	0.1	8.0	6:1	6:1	6:1
	1-7/16	70.0	21.2-70.0	1.5	0.0	20.0	6:1	6:1	6:1
		70.0	Total	3.5	0.0				6:1

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
98	2"	20.2	0-20.2	59.0	2.9	8.0	6:1	3:4	2.6:1
	1-7/16	75.0	20.2-75.0	0.0	0.0	10.0	6:1	6:1	6:1
		75.0	Total	59.0	0.8	10.0			2.6:1
99	2"	20.2	0-20.2	36.0	1.8	8.0	6:1	0.6:1	1.6:1
	1-7/16	76.0	20.2-76.0	8.0	0.1	15.0	6:1	6:1	6:1
		76.0	Total	44.0	0.6				2.8:1
100	2"	20.3	0-20.3	17.0(6)	0.8	2.0	6:1	0.6:1	1.7:1
	1-7/16	74.0	20.3-74.0	Grouted from hole 102 (7)					
101	2"	20.3	0-20.3	2.0(6)	0.1	5.0	2:1	2:1	2:1
	1-7/16	75.0	20.3-75.0	23.0(6)	0.4	15.0	2:1	6:1	2.3:1
		75.0	Total	25.0(6)	0.3				2.3:1
102	2"	20.3	0-20.3	12.0(6)	0.6	2.0	2:1	0.6:1	0.7:1
	1-7/16	36.0	20.3-36.0	191.0(6)	12.2	15.0	3:1	0.6:1	1.2:1
		62.0	36-62.0	0.0	0.0		No grouting required		
		62.0	Total	203.0(6)	3.3				1.2:1
103	2"	20.5	0-20.5	0.0	0.0		No grouting required		
	1-7/16	36.0	20.5-36.0	3.0	0.2	20.0	4:1	4:1	4:1
		56.0	36-56.0	0.0	0.0		No grouting required		
		56.0	Total	3.0	0.1				4:1
104	2"	20.2	0-20.2	0.0	0.0		No grouting required		
	1-7/16	56.0	41-56.0	0.0	0.0	25.0	6:1	6:1	6:1
		56.0	20.2-41.0	5.0	0.3	13.0	6:1	6:1	6:1
		56.0	Total	5.0	0.1				6:1

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

Hole	Size	Depth (Feet)	Zone	Cubic Ft. Cement	Cubic Ft. per ft.	Final Gauge Pressure (P.S.I.)	W/C Start.	W/C Finish	W/C Average
105	2"	20.3	0-20.3	0.0	0.0		No grouting required		
	1-7/16	60.0	20.3-60.0	0.0	0.0	12.0	6:1	6:1	6:1
		60.0	Total	0.0	0.0				6:1
106	2"	20.3	0-20.3	9.0	0.4	0.0	6:1	0.6:1	0.9:1
	1-7/16	61.0	20.3-61.0	30.0	0.7	10.0	3:1	1:1	1.5:1
		61.0	Total	39.0	0.6				1.2:1
107	2"	20.3	0-20.3	13.0	0.6	8.0	6:1	0.6:1	3.2:1
	1-7/16	30.0	20.3-30.0	201.0	20.7	12.0	2:1	0.6:1	1.1:1
		68.0	30-68.0	0.0	0.0	8.0	6:1	6:1	6:1
		68.0	Total	214.0	3.1				1.2:1
108	2"	12.0	0-12.0	7.0	0.6	8.0	0.6:1	0.6:1	0.6:1
	1-7/16	20.3	12-20.3	98.0	11.8	0.0	6:1	0.6:1	1.4:1
		36.0	20.3-36.0	68.0	4.3	16.0	4:1	1:1	2:1
		73.0	36-73.0	6.0	0.2	8.0	3:1	2:1	2.5:1
		73.0	Total	179.0	2.5				1.6:1
109	2"	20.5	0-20.5	27.0	1.3	8.0	3:1	1:1	2:1
	1-7/16	24.0	20.5-24.0	178.0	50.9	10.0	3:1	0.6:1	0.9:1
		54.0	24-54.0	51.0	1.7	8.0	4:1	2:1	3:1
		70.0	54-70.0	0.0	0.0		No grouting required		
		70.0	Total	256.0	3.7				1.4:1
110	2"	21.0	0-21.0	0.0	0.0		No grouting required		
	1-7/16	31.0	21-31.0	60.0	6.0	15.0	1:1	1:1	1:1
		60.0	31-60.0	239.0	8.2	8.0	3:1	0.7:1	1.1:1
		60.0	Total	299.0	5.0				1:1
	Total	4666.5	Total	6786.7	Ave. 1.45 bags per foot of hole				

TABLE I
FOUNDATION GROUTING ON COLD BROOK DAM

(1) 9 c.f. sand added to last batch
P = Primary hole
S = Secondary hole
T = Tertiary hole

(2) Variable due to surface leaks.

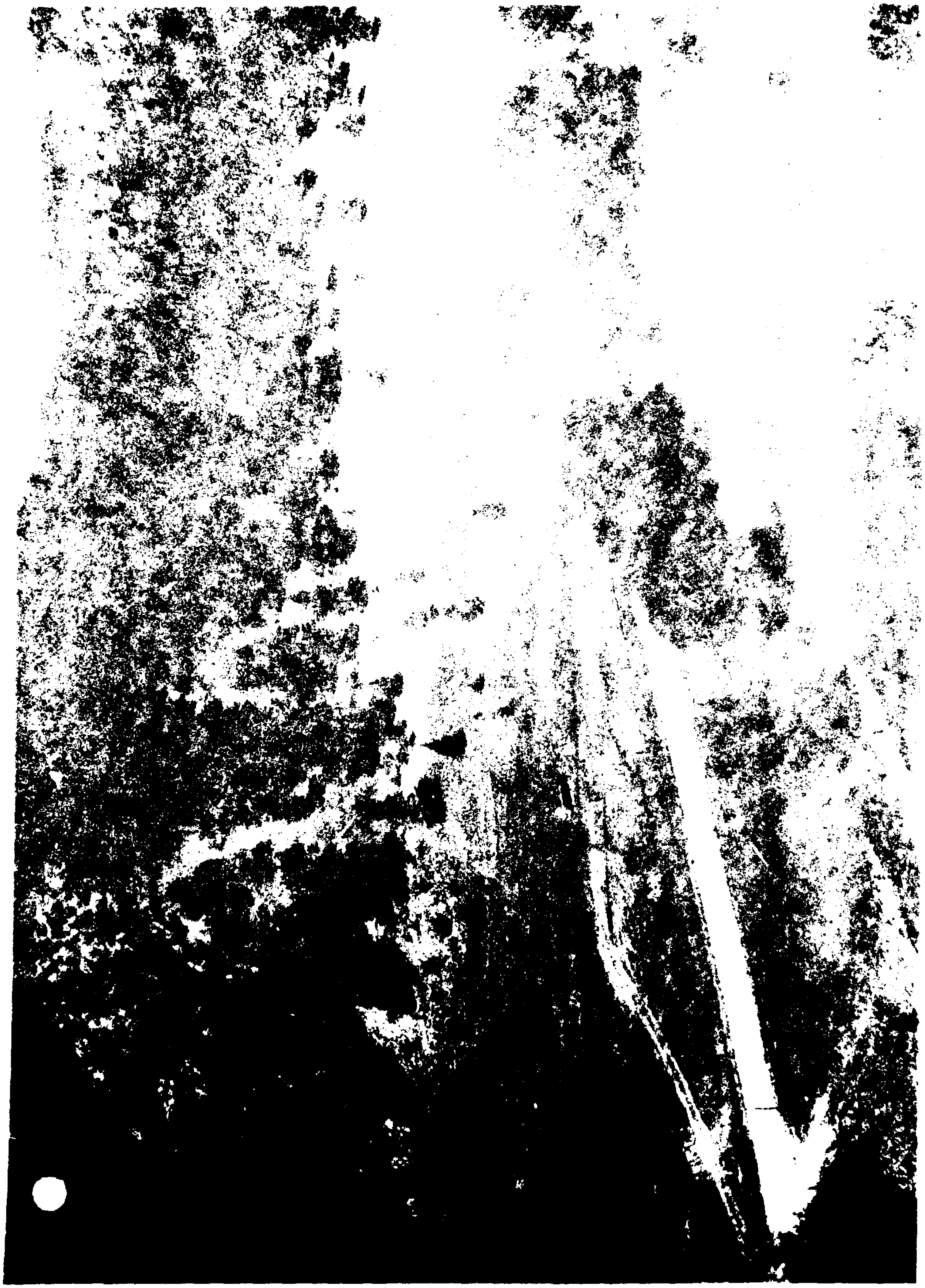
(3) Reason for large grout take not known.

(4) A large part of this grout was mixed with deteriorated shale in top 5' zone. When area was frozen, a hole would prove tight. After it was drilled deeper, ground thawed and hole again leaked.

(5) Note Holes 92 - 110 incl., grouted in groups of two to four beginning at 92 and moving progressively up the left abutment slope to hole 110.

(6) 100, 101, and 102 communicated in two zones. Part of 203 sacks charged to 102 went to grout portions of 100 and 101.

PHOTOGRAPHS



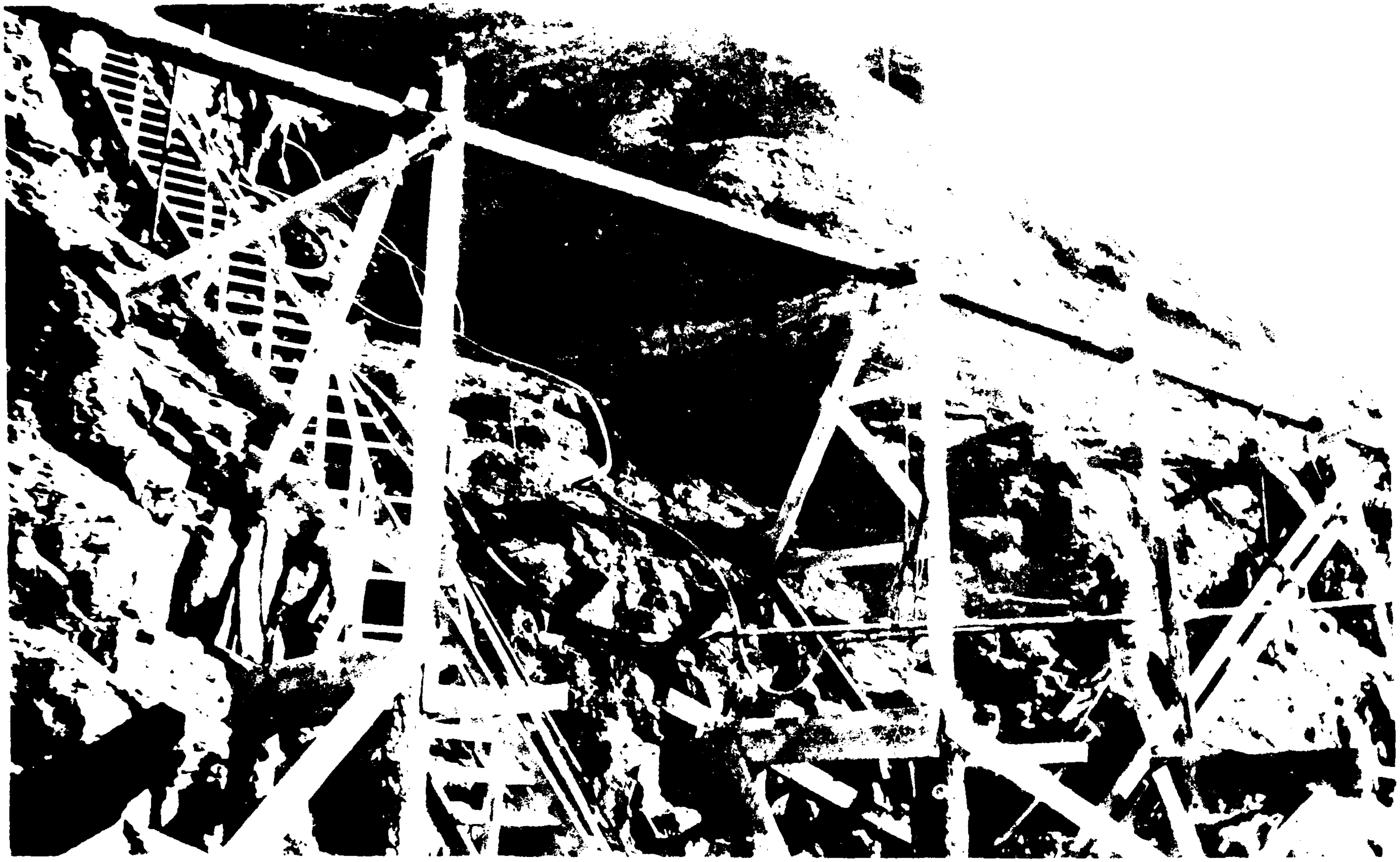


PHOTO NO. 4 VIEW OF FOUNDATION EXCAVATION ON EAST ABUTMENT DURING DRILLING AND GROUTING OPERATIONS.

PHOTO NO. 5 GENERAL VIEW OF FOUNDATION EXCAVATION ON WEST ABUTMENT.

PHOTO NO. 6 VALLEY SECTION OF CUT-OFF TRENCH BEFORE ROCK EXCAVATION. NOTE SAND BAG DIKES ON UPSTREAM AND DOWNSTREAM TOES OF CUT-OFF TRENCH.

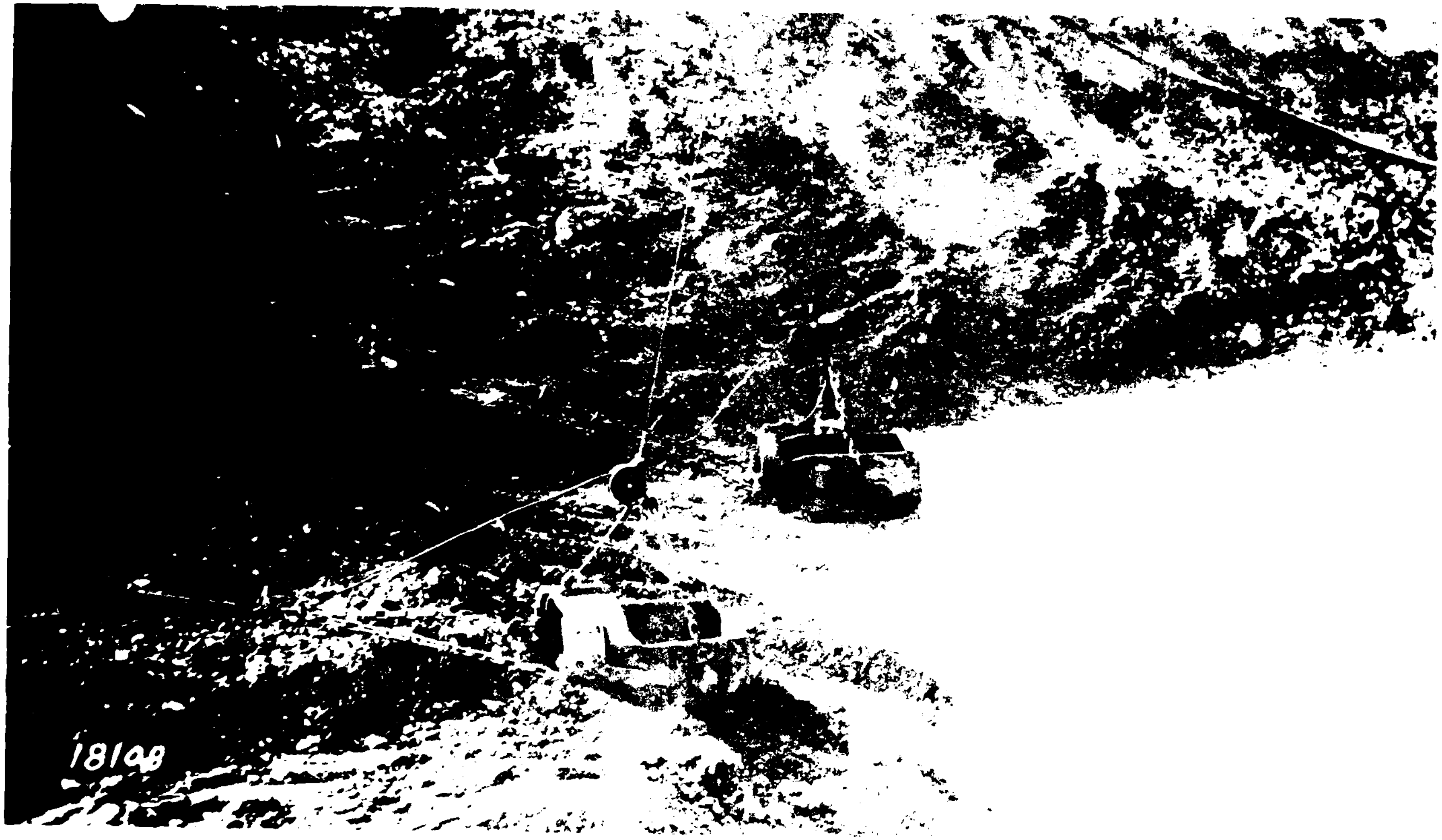
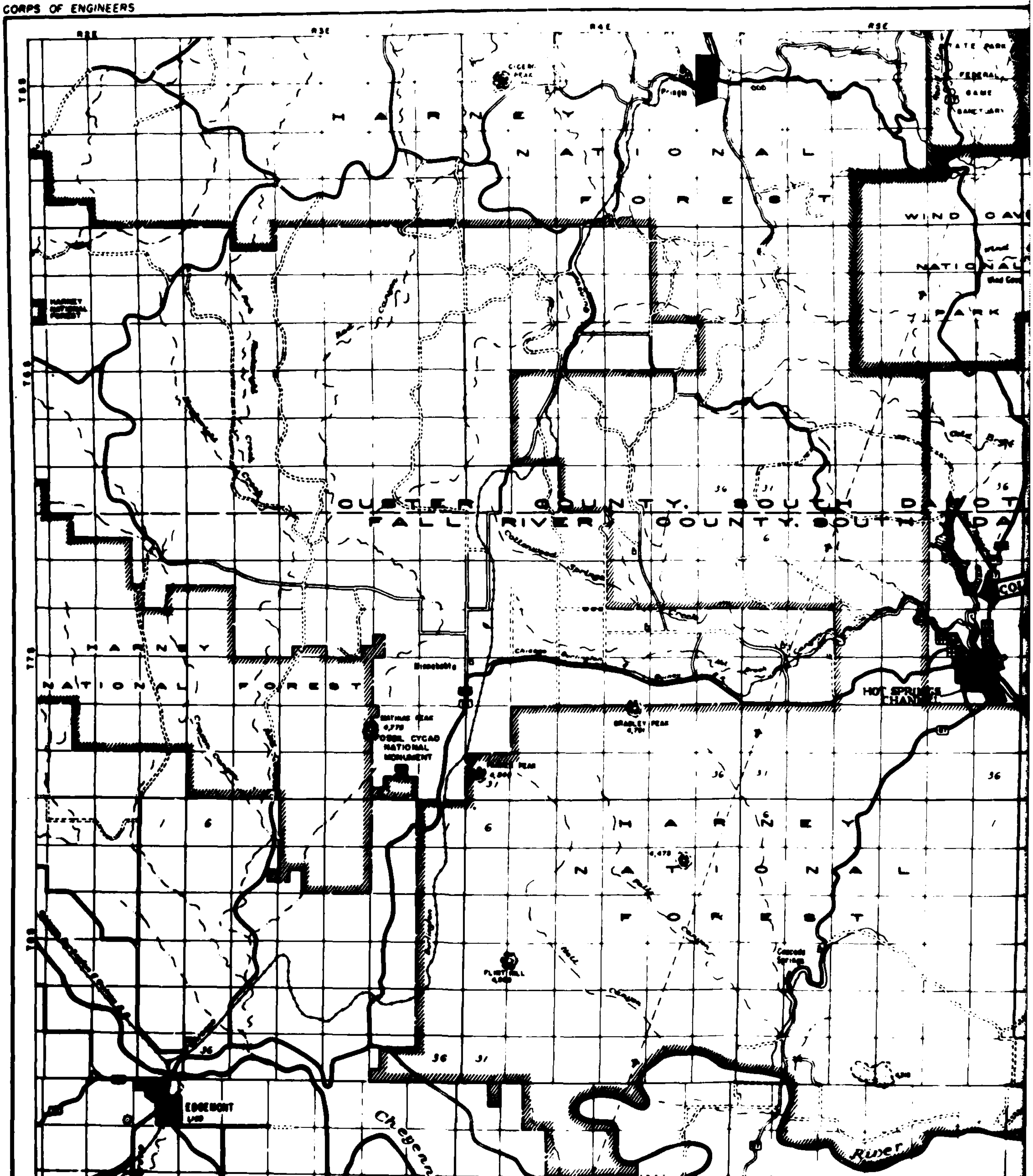
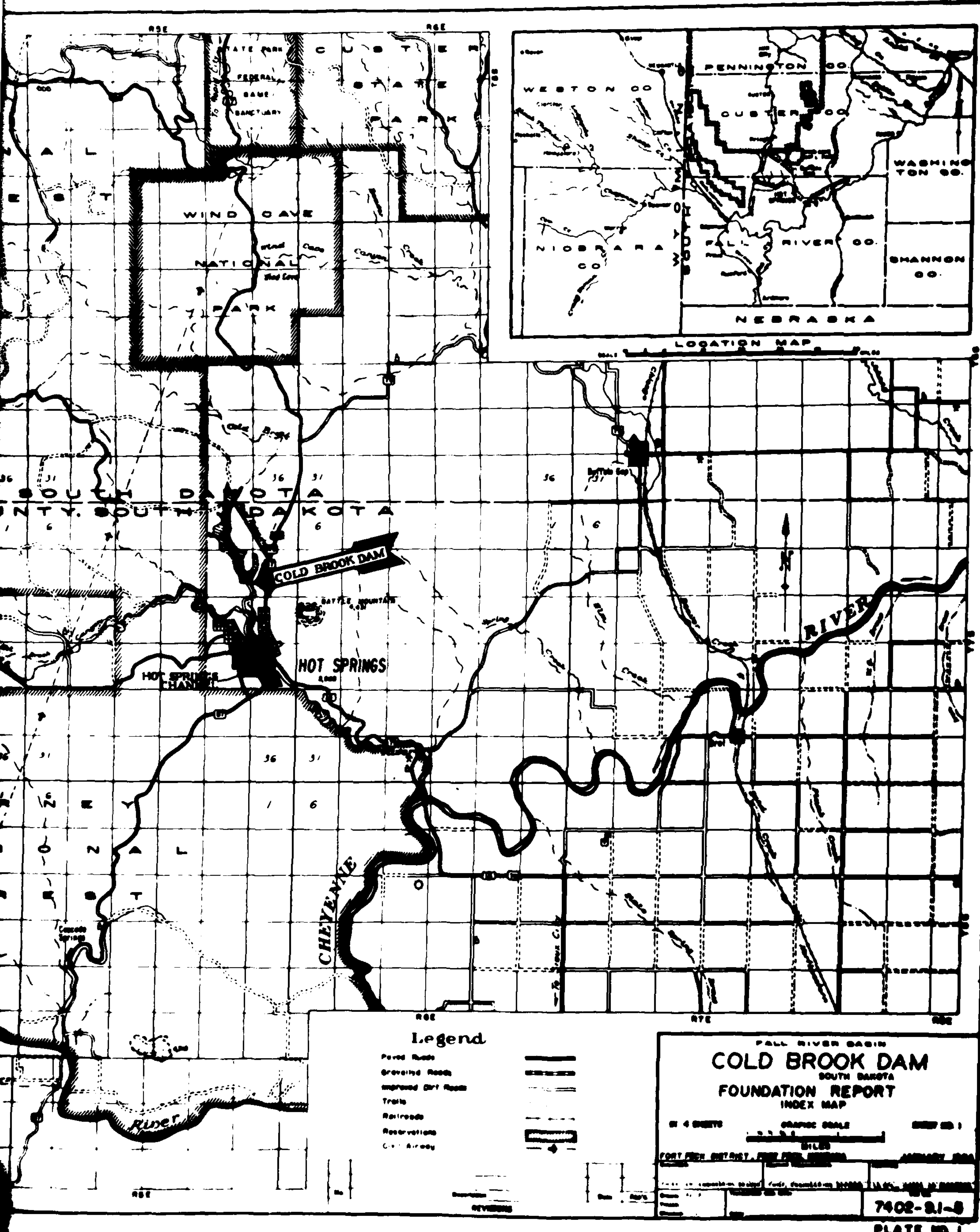


PHOTO NO. 7 [illegible]
OF REP[illegible]

[illegible] GENERAL VIEW OF DAM SITE SHOWING CONDUIT PARTIALLY IN PLACE AND INITIAL STAGE OF EMBANKMENT.

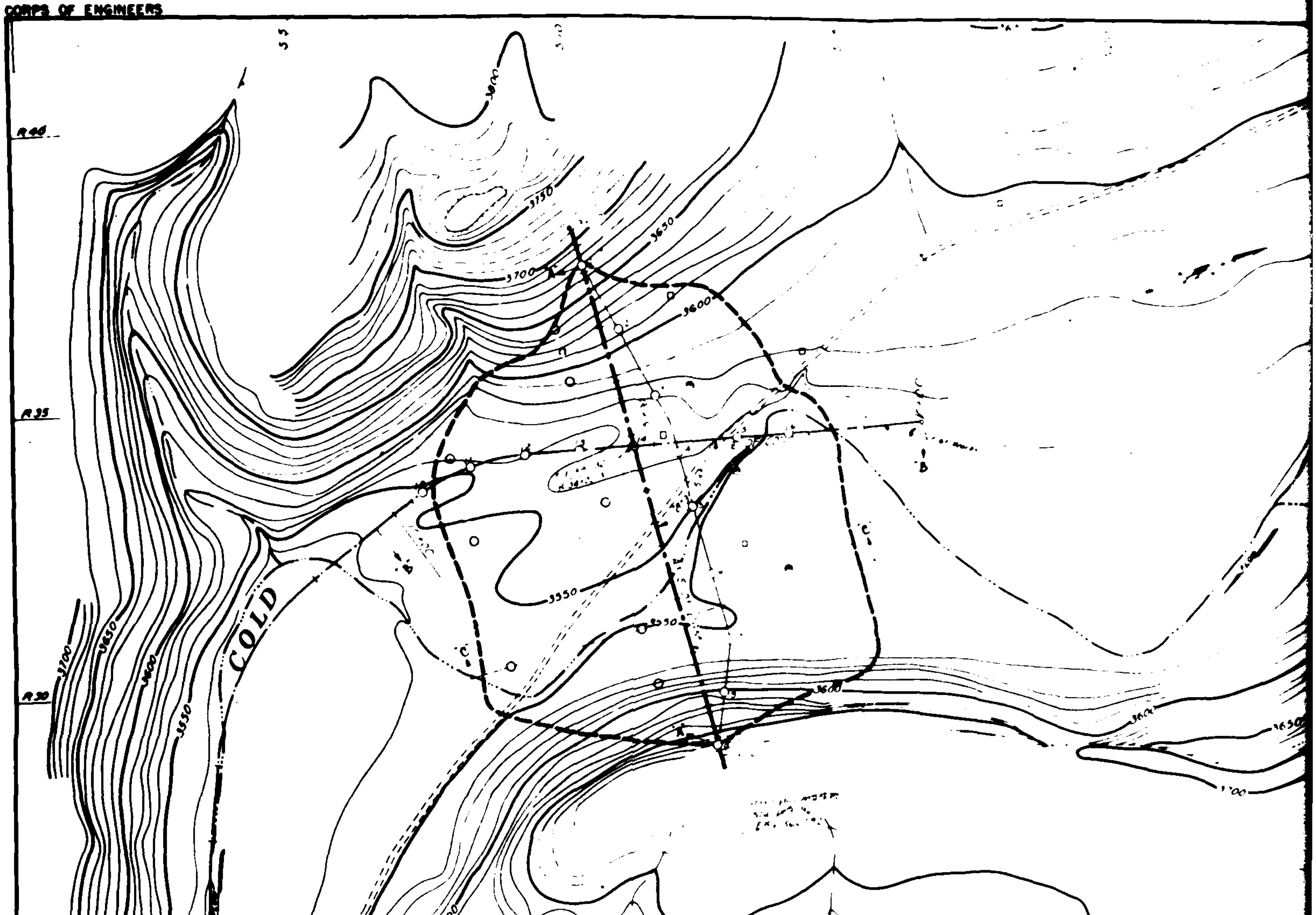
CORPS OF ENGINEERS

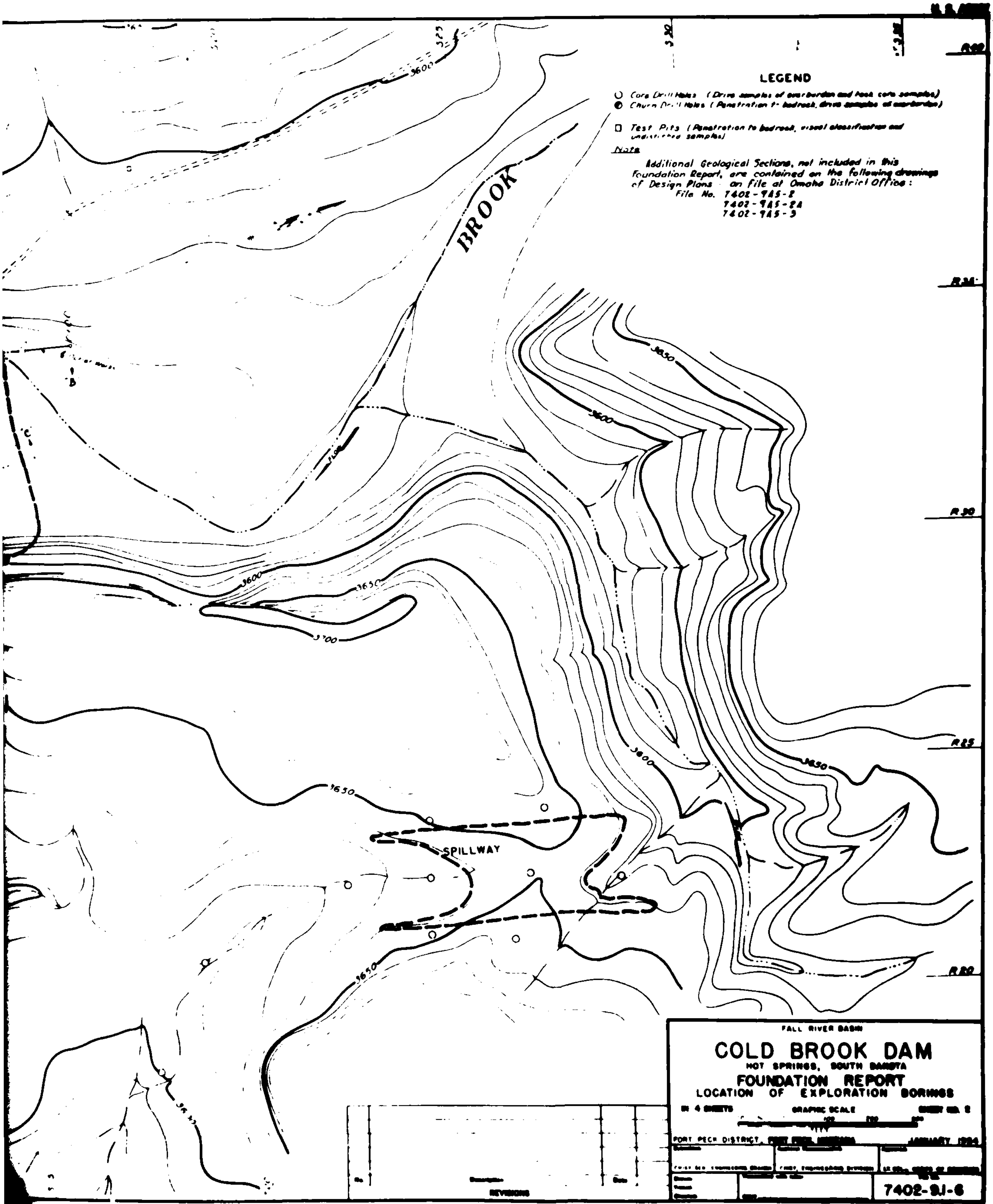



U. S. ARMY
CUSTER STATE PARK
STATE PARK FEDERAL GAME SANCTUARY
WIND CAVE NATIONAL PARK
WESTON CO.
PENNINGTON CO.
CUSTER CO.
WASHINGTON CO.
NIOBRARA CO.
FALL RIVER CO.
SHANNON CO.
NEBRASKA
LOCATION MAP
SOUTH DAKOTA
COLD BROOK DAM
BATTLE MOUNTAIN
HOT SPRINGS
HOT SPRINGS CHANNEL
RIVER
CHEYENNE
River
Legend
Paved Roads
Graveled Roads
Improved Dirt Roads
Trails
Railroads
Reservations
FALL RIVER BASIN
COLD BROOK DAM
SOUTH DAKOTA
FOUNDATION REPORT
INDEX MAP
GRAPHIC SCALE
MILES
7402-9.1-8
REVISIONS
PLATE NO. 1

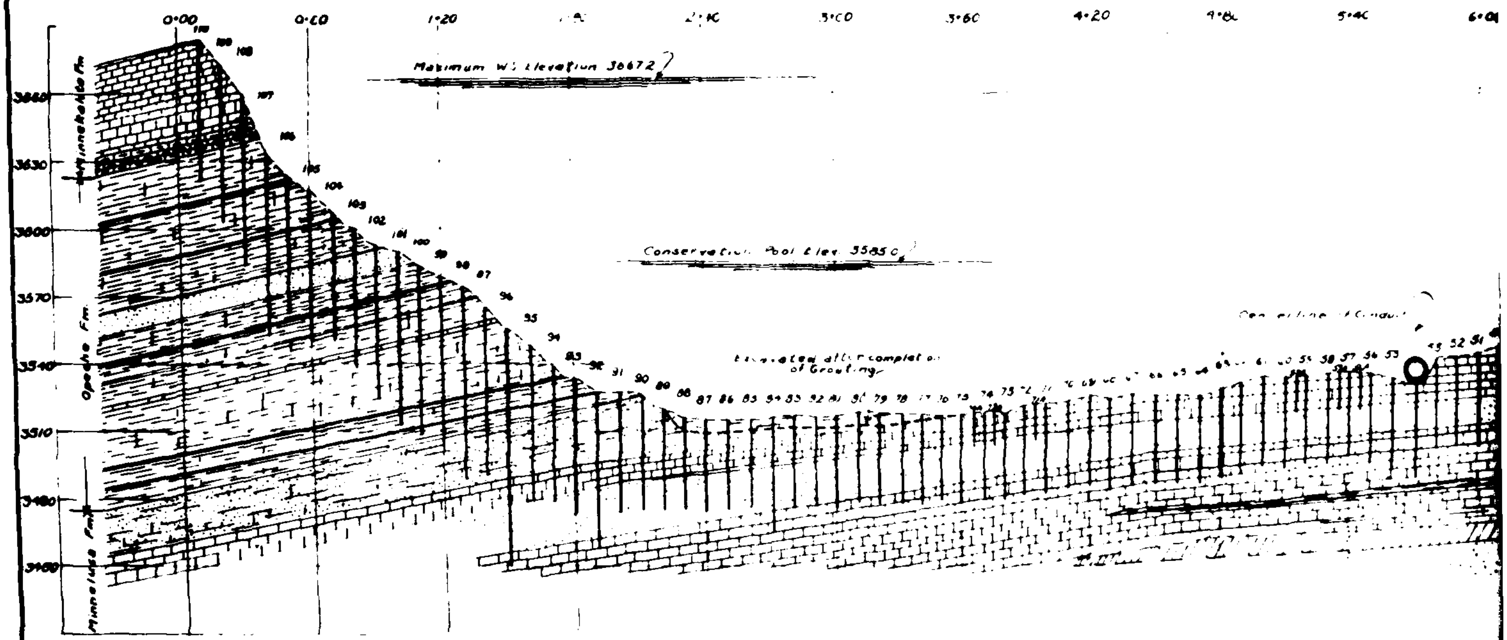
2

CORPS OF ENGINEERS

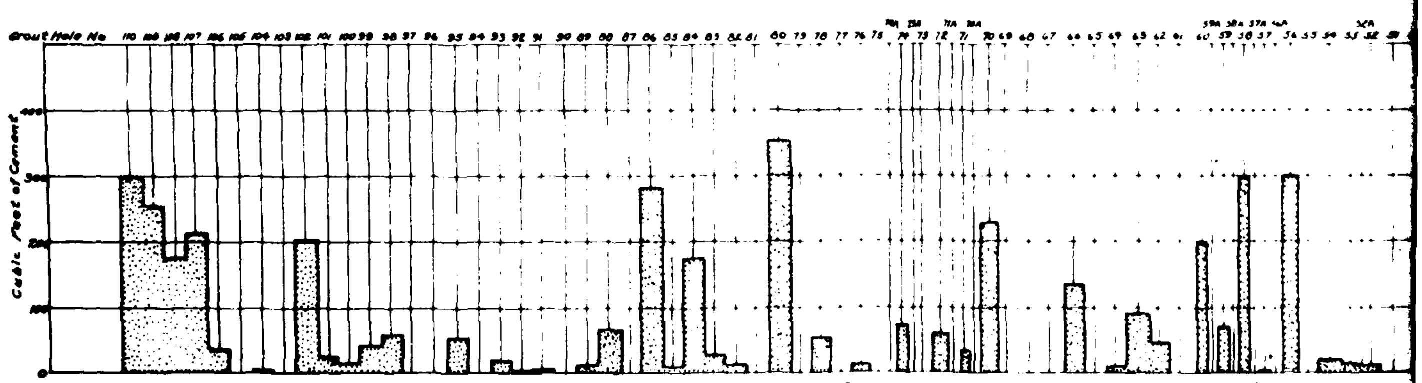



LEGEND
Core Drill Holes (Drive samples of overburden and rock core samples)
Churn Drill Holes (Penetration to bedrock, drive samples of overburden)
Test Pits (Penetration to bedrock, visual classification and undisturbed samples)
Note
Additional Geological Sections, not included in this Foundation Report, are contained on the following drawings of Design Plans on file at Omaha District Office:
File No. 7402-9AS-2
7402-9AS-2A
7402-9AS-3
BROOK
SPILLWAY
3600
3650
3700
R30
R25
R20
FALL RIVER BASIN
COLD BROOK DAM
HOT SPRINGS, SOUTH DAKOTA
FOUNDATION REPORT
LOCATION OF EXPLORATION BORINGS
IN 4 SHEETS
GRAPHIC SCALE
SHEET NO. 2
FORT PECK DISTRICT
REVISIONS
7402-9J-6
PLATE NO. 2

2



Geological Section Along Center line of Cutoff Trench
Showing Location and Depth of Grout Holes and Final Excavation Line
Section 4-A

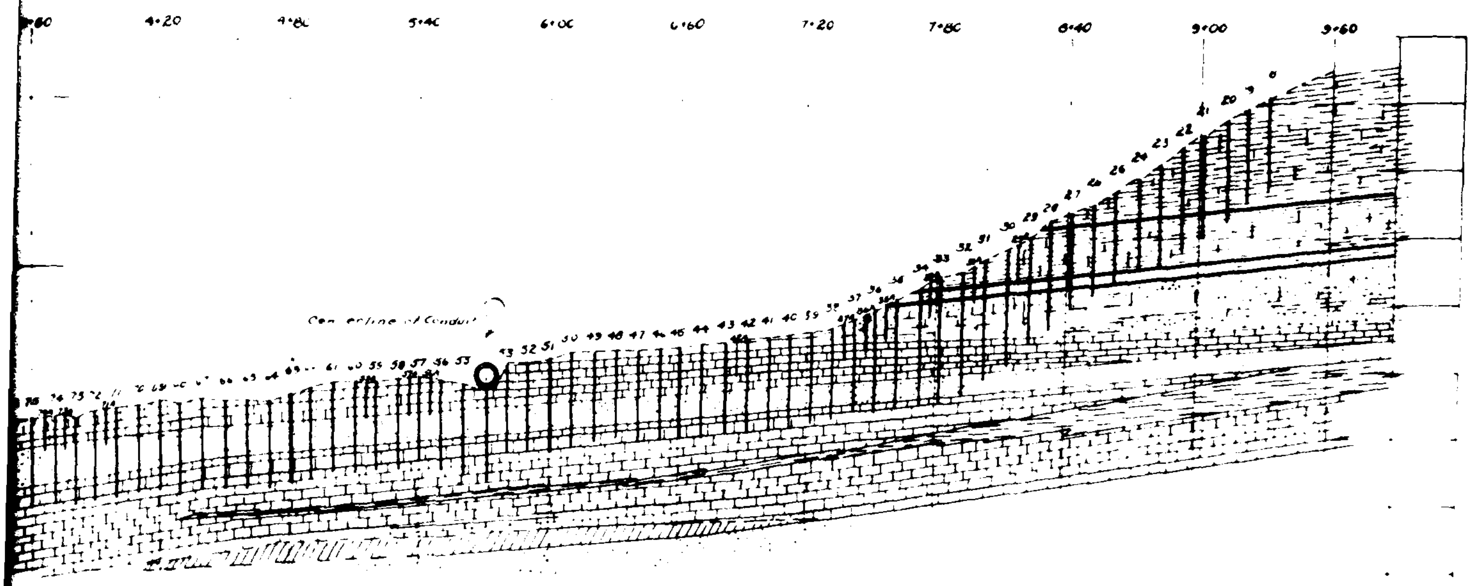


Bargraph Showing Cubic Feet of Cement Injected in Each Grout Hole

LEGEND

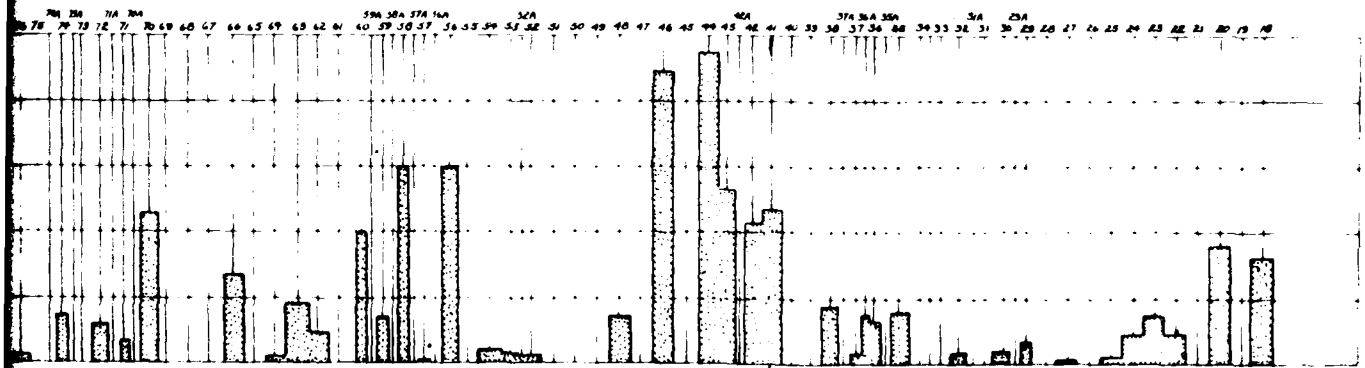
- Limestone
- Argillaceous Limestone
- Fine grained Buff and Orange Sandstones
- Jointed, Shaley and Limey Sandstones
- Red, Soft, Jointed Shales
- Solution Channel with Redeposited Limey Clay
- Final Excavation Line

CORPS OF ENGINEERS



Geological Section Along Center line of Cutoff Trench
...g Location and Depth of Grout Holes and Final Excavation Line
Section A-A

30 0 30 60 Feet
Horizontal Scale
30 0 30 60 Feet
Vertical Scale



...rgraph Showing Cubic Feet of Cement Injected in Each Grout Hole

Note

For Plan Showing location of Cutoff Trench Refer to Plate

Total Cement injected Entire Cutoff Curtain 6786.7 Sacks

Total drilling entire Cutoff Curtain 4046.8 Lin Ft

NO	DESCRIPTION	DATE	APP'D
REVISIONS			

FALL RIVER BASIN

COLD BROOK DAM

HOT SPRINGS, SOUTH DAKOTA

FOUNDATION REPORT

CUTOFF CURTAIN

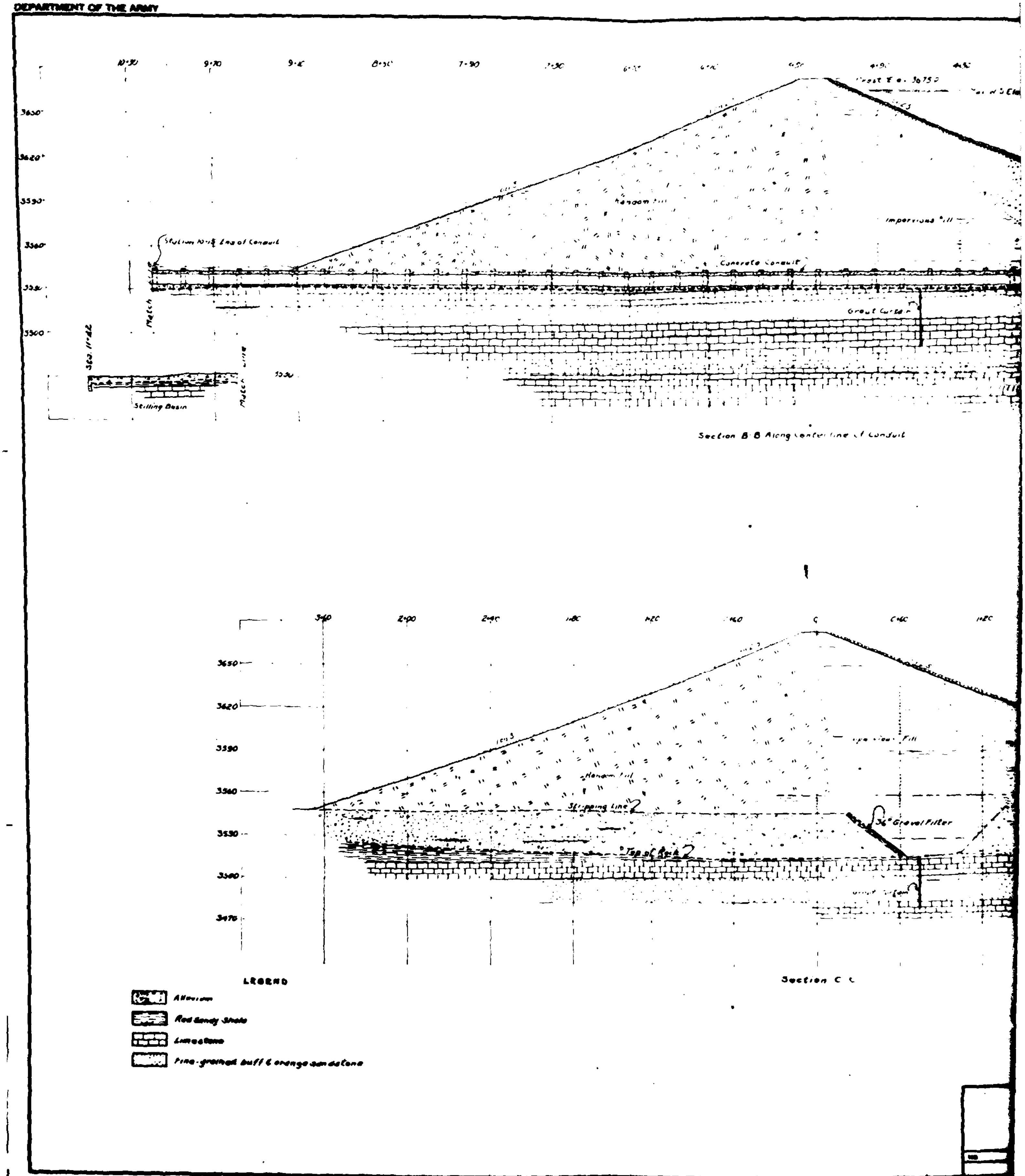
IN 4 SHEETS SCALE AS SHOWN SHEET NO. 3

PORT PECK DISTRICT, FORT PECK, MONTANA JANUARY 1954

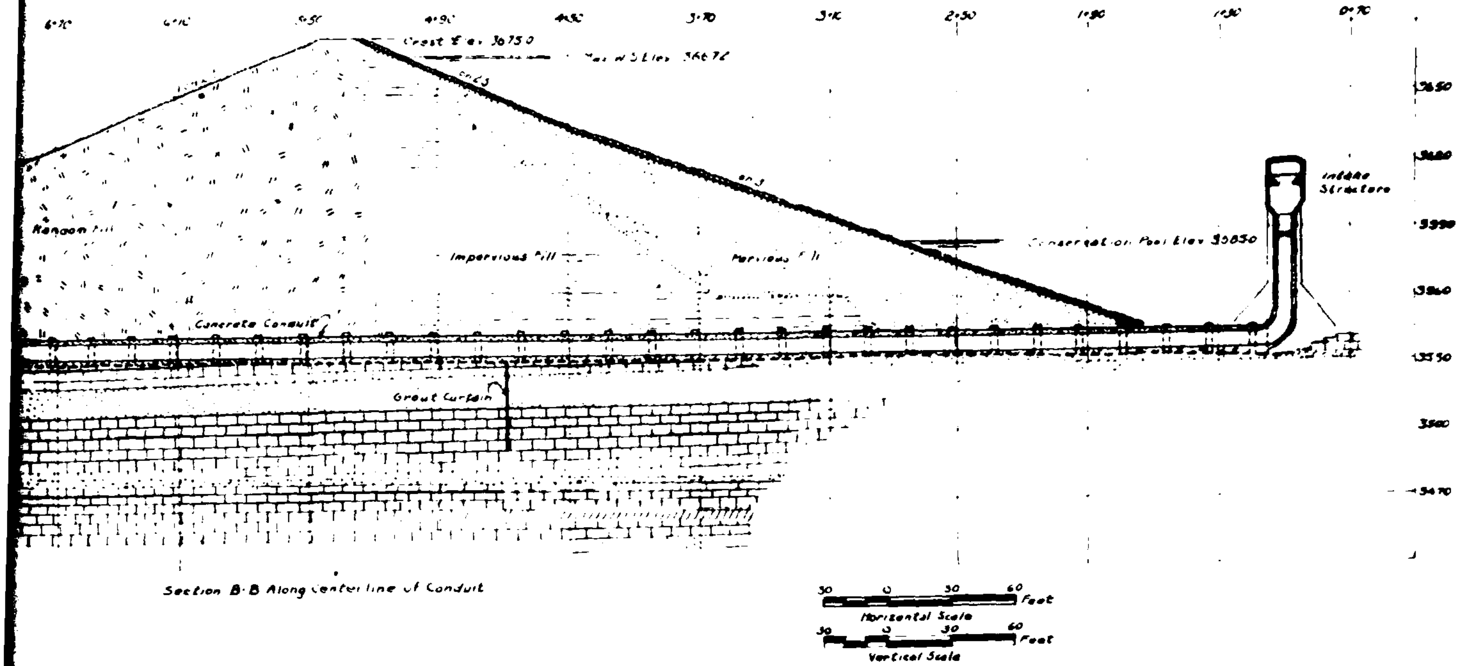
7402-8.1-7

PLATE NO. 3

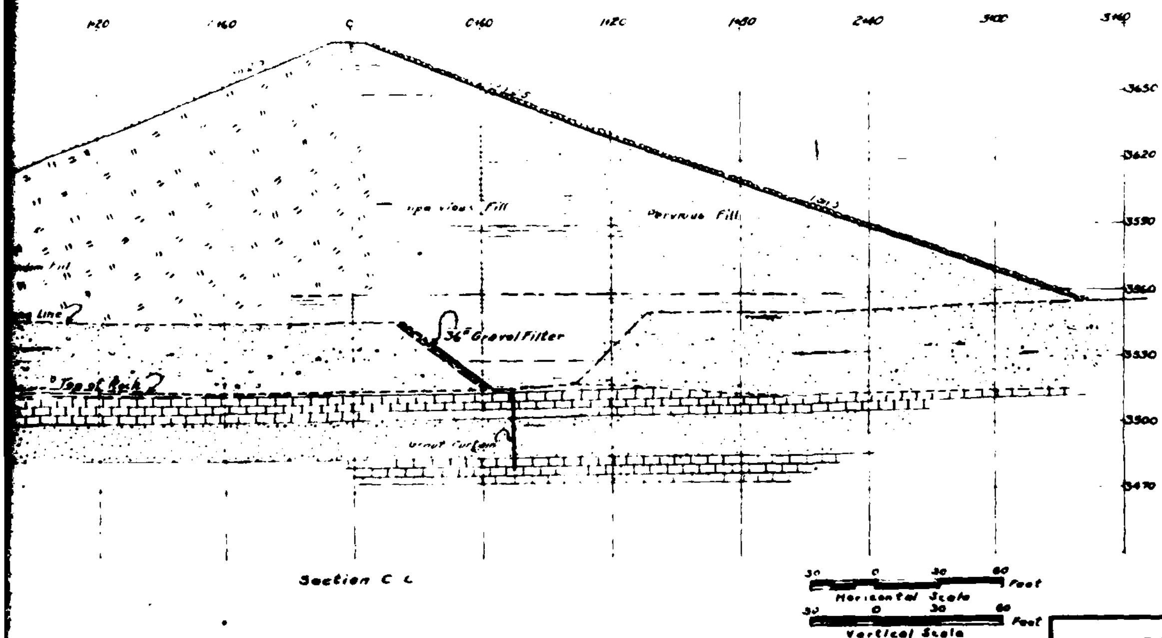
DEPARTMENT OF THE ARMY



CORPS OF ENGINEERS



Section B-B Along Centerline of Conduit



Section C-C

REVISIONS

FALL RIVER BASIN
COLD BROOK DAM
HOT SPRINGS, SOUTH DAKOTA

FOUNDATION REPORT
EMBANKMENT & FOUNDATION SECTIONS

IN 6 SHEETS SCALE AS SHOWN SHEET NO. 4

FORT PECK DISTRICT, FORT PECK, MONTANA JANUARY 1954

7402-9.1-8

PLATE NO. 4

2

APPENDIX A

APPENDIX A

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I. INTRODUCTION

1.1. LOCATION AND GENERAL DESCRIPTION. Cold Brook Dam is located approximately 3 miles north of Hot Springs, South Dakota. The dam is situated on Cold Brook, 1.25 miles north of the confluence of Cold Brook and Hot Brook in S11, T7S, R5E (See Plate A-1). The dam consists of a rolled earth filled embankment having a maximum height of 129 feet and a total length of 920 feet, an ungated sharp crested weir spillway, and an ungated circular concrete outlet structure.

1.2. CONSTRUCTION AUTHORITY. The Cold Brook Dam Project was authorized by the Flood Control Act of 1941, House Document H655/76/3, Fall River Basin.

1.3. PURPOSE OF REPORT. This report has been prepared in accordance with requirements set forth in Regulation No. 1110-1-1801, Engineering and Design Construction Foundation Reports, Office, Chief of Engineers dated 15 December 1981. The purpose of this report is to compile a record and analysis of the information obtained from the extension of the original grout curtain at Cold Brook Dam. Included is information concerning the site geology, history of previous grouting, grouting procedures, drilling, pressure testing and grouting information.

1.4. GROUTING HISTORY. A grout curtain consisting of a single line of vertical grout holes extending across the axis of the cutoff trench and up to the crest elevation of each abutment was installed in 1950 during construction of Cold Brook Dam (See Cold Brook Dam Foundation Report, Plate 3). This treatment was due to the highly fractured and brecciated condition of the Minnelusa Formation as determined by exploratory drilling.

1.5. CONTRACTOR AND CONTRACT SUPERVISION. The W. G. Jaques Company of Des Moines, Iowa was awarded the contract for extending the grout curtain at Cold Brook Dam in September, 1978. Work was begun on 20 September 1978 and completed on 10 February 1979. Supervision of the contract was provided by the Omaha District Corps of Engineers, Construction Division through the South Dakota Area Engineer.

CHAPTER 2 - FOUNDATION EXPLORATIONS

2.1. EXPLORATIONS DURING CONSTRUCTION. After completion of the original grout curtain, the left abutment was cut back to a 1 on 1 slope. This excavation revealed that much of the Minnekahta limestone was highly fractured and laminated. In April and May 1954 four exploratory holes were drilled and pressure tested in the left abutment to determine the effectiveness of the existing grout curtain and to further determine the condition of the Minnekahta Formation. The limestone proved to be grouted tight to within ten feet of the end of the abutment. Holes G-1 and G-6, 20 and 30 feet east of the embankment respectively (Plate A-4), had considerable water take. The boring located farthest east, G-2, showed a water take in the lower argillaceous limestone. Concern was expressed in the Cold Brook Dam Foundation Report that the water reaching the limestone strata at maximum flood pool

elevation 3667.2 could find a path around the grout curtain and cause erosion of the fill material at the abutment-embankment contact. This concern was again expressed in the 2nd Periodic Inspection Report, September 1975, and a recommendation was made to extend the grout curtain into the left abutment based on further exploration.

2.2. ADDITIONAL EXPLORATIONS. More exploration was conducted in 1977 on the left abutment. Three angle holes (30° from the vertical) and two vertical holes were drilled twenty feet upstream of the centerline on the left abutment and pressure tested (See Plates A-2 and A-3). Water pressure tests conducted in drill hole 77-9 (30° angle) showed an average water take of 26.6 gallons per minute. Core recovered from these borings indicated the limestone was highly fractured with open and filled or partially filled fractures.

CHAPTER 3 - GEOLOGY

3.1. GENERAL SITE GEOLOGY. Cold Brook Dam lies in the Fall River Drainage Basin located on the southern edge of the Black Hills Dome. Geologic formations encountered at the dam site are of sedimentary origin. They include in ascending order the Minnelusa Formation (Pennsylvanian); the Opeche Formation (Permian); the Minnekahta Formation (Permian); and Spearfish Formation (Permo-Triassic). Pleistocene and recent stream gravels are present as overburden material.

3.2. STRATIGRAPHY. The formations grouted were the Opeche Formation and the Minnekahta Formation (See Photo No. A-1).

(a) Opeche Formation. The Opeche Formation consists of purple, red and buff or yellow shales and siltstones interspersed with thin bands of sandy and clayey vari-colored limestones and sandstones. The formation obtains a thickness of approximately 45 feet. The top of the formation is conspiciously marked by a five foot zone of soft, limey, purple shale underlain by alternate zones of red sandy shale, limey sandstones, thin limestones, and sandstones. The sandy shale beds vary from 1 to 4 feet in thickness and are characterized by vertical joints and horizontal bedding planes filled with red clay partings.

(b) Minnekahta Formation. This formation consists of about 48 feet of fine-grained, thin-bedded to massive limestone, ranging in color from purple to pink to gray (Photos A-2 and A-3). Its thin bedding is characteristic, but the layers are tightly cemented together and ledges present a massive appearance. The Minnekahta limestone forms the cap rock of the valley rim on both sides of Cold Brook Dam. Due to the eastward dip of the formations, the Minnekahta lies above the crest elevation of the dam on the west abutment, but constitutes the upper 48 feet of the east (left) abutment. In both outcrops and cores the formation consists of alternate members of pure, dense and thin-bedded limestone and layers of softer, more massive argillaceous limestone. Examination of core reveals that the pure limestone members have frequently been partly dissolved along bedding and joint planes and thus appear as a series of thin, platy beds with partings of calcite or residual

red clay. The argillaceous members have been less dissolved and yield solid core. Stylolites and small vugs or cavities are rather common throughout the formation, particularly in the pure members. Examination of the Minnekahta limestone in an exposure a short distance downstream of the embankment indicates the limestone contains high angle fractures at approximately 90 degrees to each other. One open fracture over 2 inches wide was detected, other fractures were filled or partially filled.

3.3. STRUCTURE. The geologic structure in the area surrounding the dam is characterized by several slight changes in the rate and direction of dip. Variations of from 5 to 35 degrees in dip are encountered. Along the axis of the dam the dip averages 5 to 6 degrees nearly due east, and the strike is normal to the axis. The dip is more consistent with the regional trend in the spillway, varying from 7.5 to 10 degrees in a south 20 degrees east direction. No wide scale faulting is known to occur within the reservior area but occasional faults of slight displacement are encountered along with the outcrop of the Minnekahta Formation, particularly along the outward facing escarpment of this formation along the valley walls.

CHAPTER 4 - GROUTING

4.1. GROUT CURTAIN DESIGN. After the above mentioned explorations were performed it was proposed that a grout curtain extending approximately 100 feet into the abutment, with an average depth of 65 feet, be installed in the limestone of the left abutment. It was decided the curtain would consist of a single line of grout holes with primary holes on 20 foot centers. These holes would be split-spaced as necessary down to quaternary holes, spaced on 2.5 foot centers. Primary and secondary holes would be vertical, and tertiary and quaternary holes would be inclined 30° toward the embankment. The stage grouting method was chosen, with stage I extending from elevation 3670 to 3645 and stage II from elevation 3645 to approximately elevation 3610 (ten feet into the Opeche shale).

Materials chosen for the grout mixes were water, cement, sand, and bentonite (1%-4% by weight of the cement), with water - cement ratio ranging from 5:1 to 2:1.

The pressures used during water pressure testing and grouting were monitored by a gauge at the top of the hole (Photo No. A-7). The maximum pressure used during water pressure tests was 1 pound per square inch per foot of depth of the stage being tested, never to exceed 75 psi. The following formula was used for determining the total pressure at the top of the packer when water pressure testing:

Total pressure (psi) = Gauge pressure (psi) + (height of gauge [feet] + depth to top of packer [feet]) (0.433 psi/ft) (1)

The following formula was used for determining the total pressure at the top of the packer when pumping grout, in conjunction with Graph 4.0:

Total pressure = Gauge pressure + (height of gauge + depth to top of packer) x (weight of 1-foot column of grout taken from graph [psi]) (2)

Units are the same as in formula (1).

Drilling data (Table T-1), Pressure Testing data (Table T-2) and Grouting data (Table T-3) for all the holes is summarized in the tables following the text.

4.2. EQUIPMENT. A truck-mounted, Mobile, Model B-53 rotary drill rig was used to drill the grout holes (Photo No. A-4). The circulation fluid used was either air or water. A standard grout plant consisting of a mixer and agitating sump was used (Photos Nos. A-5 and A-6). When sand was used, it was added to the grout when it was in the sump. A positive displacement Moyno pump was used to pump the grout.

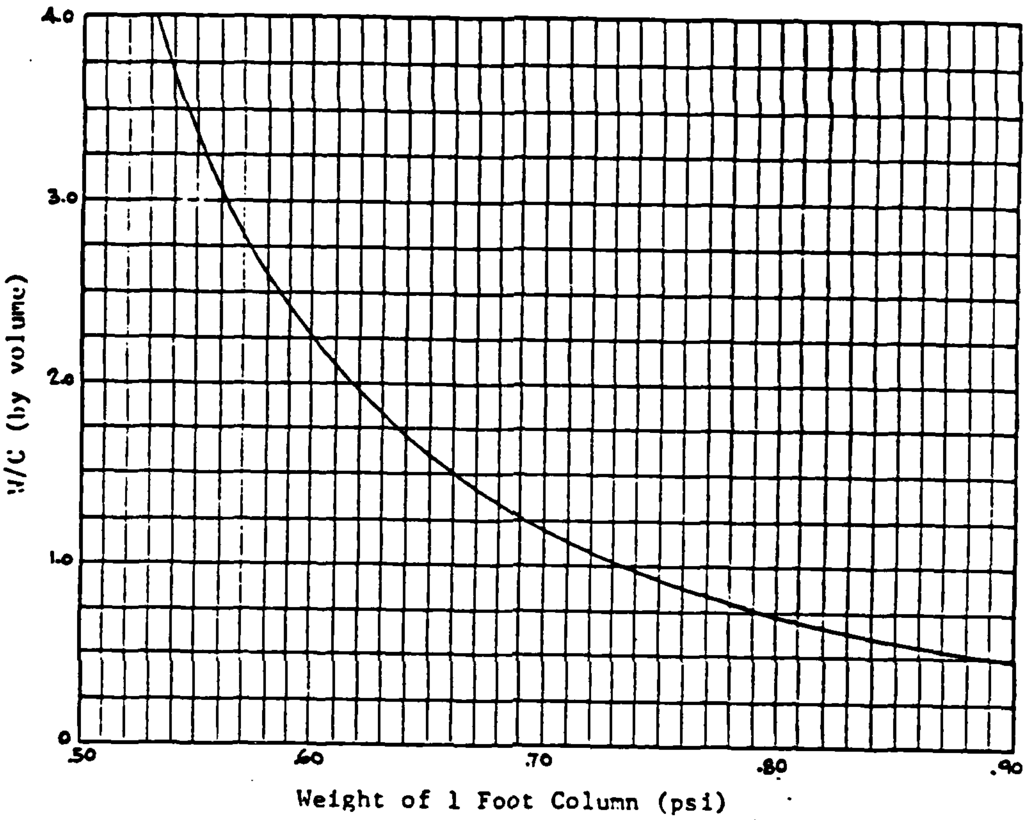
4.3. ADDITIONAL HOLES. Holes were added to account for a discrepancy between the actual abutment/embankment contact and the contact as shown on the plans. This contact was found to be 30 feet further east than indicated on the plans. Two tertiary holes were eliminated, -(0+85), CL, 30° and -(0+75), CL, 30°, and two others were added, 0+24, CL, 25° and 0+50, CL, V. In addition, two other holes, -(0+25), CL, V and 0+2.5, CL, V, were added due to a large grout take in 0+00, CL, V. The nine quaternary holes were offset 1½ feet upstream, drilled, and grouted. The fifteen fifth order, or quintary holes were added to tighten areas that took large amounts of grout. Grout holes 0+15, CL, 45° and 0+50, 2.5U, V were drilled to investigate an area of broken rock encountered in 0+50, CL, V and to determine the contact between the Minnekahta and Opeche Formations.

4.4. STAGES. The primary holes were not staged. They were drilled to final depth and then pressured tested through packers. The holes were grouted from bottom to top using packers which were raised in varying increments of length to the top of the hole (see Table T-1A). The secondary, tertiary, and quaternary holes were drilled to the bottom of the first stage (35 feet) and pressure tested regardless of any air or water loss. The second stage (to 65 feet) was treated in a similar manner.

The top of ground was used as the top of the grout curtain. Large quantities of grout were apparently injected into the area between the top of ground and elevation 3670, the specified top of grout curtain (maximum pool elevation is 3667.2). For example, 2127 sacks of cement, 3100 pounds of bentonite and 780 cubic feet of sand were placed between the ground surface and 15 feet below the surface (See Plates A-8 and A-9).

4.5. HOLE ANGLES. The primary and secondary holes were vertical. The tertiary and quaternary holes were drilled at an angle of 30° toward the embankment.

Exceptions to this were tertiary holes -(0+2.5) CL and 0+2.5, CL which were vertical and 0+24, CL. This hole was angled at 25° toward the embankment in an attempt to parallel the abutment/embankment contact. Fractures on



Graph 4.0 Unit Weight of Neat Cement Grout (after U.S. Army Corps of Engineers, 1966a)

the face of the abutment were intersected without entering the embankment. Ten quintary holes were drilled at 45' and 4 were drilled at 30' toward the embankment. Quintary hole, 0+50, 2.5U, was vertical. (See Plates A-5 through A-7).

4.6. GROUT MIXES. The grout used in the project was composed of water and cement in ratios ranging from 5:1 to 0.8:1. Bentonite in the amount of four percent was added. The initial mix for the primary through the quintary holes was 3:1. Bentonite was added to the next thicker mix and sand was added to 1:1 mixes when little or no pressure had been built up in the hole. To avoid plugging the smaller fractures prematurely, the initial mix was changed to 5:1 for the quintary holes. The mix to be reached before adding sand was changed to 0.6:1. The majority of grout placed had a 1:1 water/cement ratio, and sand, when added was in a ratio of 1:1 with cement. Grout take had decreased substantially from the primary to the quaternary holes. The average grout take for the primary holes was 87 cubic feet of grout per foot of hole grouted. The average grout take for the quaternary holes was 0.96 cubic feet/foot of hole and 1.7 cubic feet/foot of hole for quintary holes. The increase in grout take in the quintary holes over the quaternary holes was due to the takes which occurred near the embankment/abutment contact. The average grout take can be misleading because of the many small areas of very large grout take above Zone I. Plates A-8, A-9, and A-10 give a more realistic picture of where the grout was placed.

4.7. PROBLEMS ENCOUNTERED. Some of the initial practices were later modified in order to obtain a better grout curtain and to facilitate evaluation of data. A major change involved requiring casing to the top of the first stage to avoid placing large amounts of unnecessary grout in that area (see paragraph 4.3). Pressure testing and grouting were done through a packer at the bottom of the casing. Holes were staged at areas of lost circulation and pressure tested. Therefore, there were more than two stages in some holes. When water takes exceeded 1.5-1.8 cubic feet per minute (the maximum capacity of the pump) the area above the water take was flow tested. Water was introduced above an expandable packer and the flow was metered after it stabilized at the top of the hole. The length of time holes were pressure washed was increased to a minimum of 5 minutes or until clear water returned. This was to insure the complete removal of clay fillings and cuttings. Heaters were installed to maintain the grout at a minimum of 50'F. A coil heater (See Photo A-8) was used to heat the water at the top of the abutment and a space heater warmed the grouting shed. The changes above resulted in closer monitoring of grout placement and probably increased the effectiveness of the grout placed.

CHAPTER 5 - COST ESTIMATES AND CONCLUSIONS

5.1. COST ESTIMATES. A total of 3,141 feet of grout holes was drilled into the left abutment and a total of 16,335 cubic feet of grout was placed compared to the original estimate of 2,215 feet of drilling and 4,500 cubic feet of grout. As previously discussed, large quantities of grout and sand were unnecessarily placed above Zone I (see Paragraph 4.3). Total cost was

$267,135.50, $134,458.00 over the original estimate. The only modification, Modification No. P00001 for additional drilling and grouting, extended the contract for 89 calendar days. The entire job took 144 calendar days.

5.2. CONCLUSIONS. A review of the drilling and grouting data suggests that the additional grouting to the left abutment provided by this contract has sufficiently tightened the abutment. This would not have been possible without the addition of the quintary holes. Since the pool, to date, has not reached its maximum flood elevation, the embankment and abutment should be closely monitored when this occurs.

TABLE T - 1 DRILLING RECORD

T-1A PRIMARY HOLES

HOLE NO.	REMARKS
0+50, ℄, V	Drilled 0-30'; 0-25' fill, 25-29' broken rock. Set & grouted 32', 2½" CSG*. Drilled 31'-50': no air loss, red** @ 35'. B.H.*** 50'
0+40, ℄, V	Drilled 0-50': water loss @ surface, 0-17' fill, rock @ 17', red @ 37'. Backfilled w/grout. Set 20' CSG. Drilled 50'-80'. B.H. 80'.
0+20, ℄, V	Drilled 0-80': 100% water loss @ 40', red @ 40'. B.H. 80'.
0+00, ℄, V	Drilled 0-80': 100% water loss @ 7', red @ 40'. B.H. 80'.
-(0+20), ℄, V	Drilled 0-80': no water loss, red @ 39'. B.H. 80'.
-(0+40), ℄, V	Drilled 0-80': no water loss, red @ 40'. B.H. 80'.
-(0+60), ℄, V	Drilled 0-80': no water loss, red @ 40.5'. B.H. 80'.
-(0+80), ℄, V	Drilled 0-70': No water loss, red @ 38.0'. B.H. 70'.

* 2½" CSG = 2½'-inch diameter casing

** red @ 35' = drilling fluid turns red at 35'; signifies contact between Minnekahta and Opeche Formations

*** B.H. = bottom of hole

T-1B SECONDARY HOLES

HOLE NO.	REMARKS
0+28, ℄, V	0+30, ℄, V caved w/broken rock & angled toward embankment. Offset to 0+28, ℄, V. Drilled 0-35': caved @ surface but straight, set 10' CSG., switched to air., air loss @ 25', washed hole w/o return, pressure tested & grouted. Drilled 35'-60': grout soft during re-drill, no air loss, red @ 42', pressure tested. B.H. 60'.
0+10, ℄, V	Drilled 0-35': broken rock @ surface, water loss @ 3', set 10' CSG., switched to air, communication w/0+00, ℄, V, 0+20, 10U, V & 0+10, 10D.V., washed hole w/o return, pressure tested & grouted. Drilled 35'-60': no air loss, red @ 42', pressure tested & grouted. B.H. 60'.
-(0+10), ℄, V	Drilled 0-35': 0-4' fill & broken rock, 25% water loss, 100% water loss @ 10', W.L. 30' @ 1 hr. after drilling, pressure tested & grouted. Drilled 35'-60': no air loss, red @ 41', pressure tested & grouted. B.H 60'.
-(0+30), ℄, V	Drilled 0-35': 0-1' fill, 100% water loss @ 30', pressure tested & grouted. Drilled 35'-60': no air loss, red @ 43', pressure tested & grouted. B.H. 60'.
-(0+50), ℄, V	Drilled 0-35': 0-2' fill, no water loss, pressure tested & grouted. Drilled 35'-60': red @ 40', pressure tested & grouted. B.H. 60'.
-(0+70), ℄, V	Drilled 0-35': 100% water loss @ 33', water return @ 35', W.L. 8' @ 1 hr. after drilling, pressure tested & grouted. Drilled 35'-65': no air loss, red @ 38', pressure tested & grouted. B.H. 65'.

T-1C TERTIARY HOLES

HOLE NO.	REMARKS
0+2.5, ℄, V	Drilled 0-35': @ 20' air came out 0+00, ℄, V., pressure tested and grouted. B.H. 35'.
-(0+2.5), ℄, V	Drilled 0-35': 0-3' broken rock, grout @ 20', pressure tested & grouted. B.H. 35'.
-0+24, ℄, 25°	Drilled 0-65': 100% air loss, red @ 47', pressure tested & grouted. Redrilled to 45': no water loss. B.H. 65'.
0+15, ℄, 30°	Drilled 0-35': lost air, air came out 0+20, 10U, V, 13'-19' soft (grout?), pressure tested & grouted. Drilled 35'-65': no air loss, red @ 50', pressure tested & grouted. B.H. 65'.
0+05, ℄, 30°	Drilled 0-35': air loss @ 6.5', pressure tested & grouted. Drilled 35'-65': red @ 50', pressure tested & grouted. B.H. 65'.
-(0+05), ℄, 30°	Drilled 0-35': no air loss, pressure tested & grouted. Drilled 35'-65': red @ 41', pressure tested & grouted. B.H. 65'.
-(0+15), ℄, 30°	Drilled 0-35': No air loss, pressure tested & grouted. Drilled 35'-65': pressure tested & grouted. B.H. 65'.
-(0+25), ℄, 30°	Drilled 0-35': air loss, pressure tested & grouted. Drilled 35'-65', pressure tested. B.H. 65'.
-(0+35), ℄, 30°	Drilled 0-35': some air loss, pressure tested & grouted. Drilled 35'-65': red @ 50', pressure tested & grouted. B.H. 65'.
-(0+45), ℄, 30°	Drilled 0-35': 50% air loss, pressure tested & grouted. Drilled 35'-65': red @ 45', pressure tested & grouted. B.H. 65'.
-(0+55), ℄, 30°	Drilled 0-35'; Some air loss, bit broke in hole & offset to -(0+56), ℄, 30° for "Stage II". Pressure tested & grouted. B.H. 35'.
-(0+56), ℄, 30°	Drilled 0-65': slight air loss, red @ 45, pressure tested & grouted. B.H. 65'.
-(0+65), ℄, 30°	Drilled 0-35': no air loss, pressure tested & grouted. Drilled 35'-65': red @ 50', pressure tested. B.H. 65'.

T-1D QUATERNARY HOLES

HOLE NO.	REMARKS
0+20, 1.5U, 30°	Drilled 0-35': 1-28' slight air loss, pressure tested & grouted. Drilled 35'-65': no air loss, red @ 43', pressure tested & grouted. B.H. 65'.
0+10, 1.5U, 30°	Drilled 0-35': slight air loss @ 5', pressure tested & grouted. Drilled 35'-65': no air loss, red @ 43', pressure tested & grouted. B.H. 65'.
0+00, 1.5U, 30°	Drilled 0-35': 0-8' lost air, 8'-35' air return, pressure tested & grouted. Drilled 35-65': no water loss, red @ 46', pressure tested & grouted. B.H. 65'.
-(0+10), 1.5U, 30°	Drilled 0-35': no air loss, pressure tested & grouted. Drilled 35'-65': no water loss, red @ 45', pressure tested & grouted. B.H. 65'.
-(0+20), 1.5U, 30°	Drilled 0-35': no air loss, pressure tested & grouted. Drilled 35'-65': no water loss, red @ 45', pressure tested. B.H. 65'.
-(0+30), 1.5U, 30°	Drilled 0-35': no air loss, pressure tested & grouted. Drilled 35'-65' no water loss, red @ 46', pressure tested & grouted. B.H. 65'.
-(0+40), 1.5U, 30°	Drilled 0-35": no air loss, pressure tested & grouted. Drilled 35'-65': 20% water loss, red @ 46', pressure tested & grouted. B.H. 65'.
-(0+50), 1.5U, 30°	Drilled 0-35': no air loss, pressure tested & grouted. Drilled 35'-65': no water loss, red @ 46', pressure tested & grouted. B.H. 65'.
-(0+60), 1.5U, 30°	Drilled 0-35': no air loss, pressure tested & grouted. Drilled 35'-65': no water loss, red @ 45', pressure tested & grouted. B.H. 65'.

T-1E QUINTARY HOLES

HOLE NO.	REMARKS
0+50, 2.5U, V	Drilled 0-26': 0-25' fill, 25'-26' broken rock. Set 26', 2" CSG. Drilled 26'-35'. Charges CSG w/water (flow test). B.H. 35'.
0+22, ℄, 30°	Drilled 0-13'. Set 13', 3½" CSG. Drilled 13'-40': no water loss, pressure tested & grouted. Drilled 40'-67': red @ 45', 100% water loss @ 63', hole plugged @ 42', redrilled, flow tested, pressure tested & grouted. B.H. 67'.
0+17.5, ℄, 30°	Drilled 0-13'. Set 13', 3½" CSG. Drilled 13'-40': 50% water loss @ 34', pressure tested & grouted. Drilled 40'-65': no water loss, red @ 45', pressure tested. B.H. 65'.
0+2.5, ℄ 30°	Drilled 0-13'. Set 13', 3½" CSG. Drilled 13'-40': no water loss, pressure tested. B.H. 40'.
-(0+2.5), ℄, 30°	Drilled 0-13'. Set 13', 3½" CSG. Drilled 13'-40': no water loss, pressure tested. B.H. 40'.
0+15, ℄, 45°	Drilled 0-16', Set 16', 2½" CSG. Drilled 16'-50': 20% water loss @ 38', 100% return @ 40', pressure tested & grouted. Drilled 50'-65': 20% water loss @ 51', 90% water loss @ 60', pressure tested & grouted. Drilled 65'-72': 100% water loss @ 66', pressure tested & grouted. Drilled 72'-80': 20% water loss @ 75', pressure tested & grouted. B.H. 80'.
0+12.5, ℄, 45°	Drilled 0-16'. Set 16', 2½" CSG. Drilled 16'-50': pressure tested. Drilled 50'-65': 20% water loss @ 55', water returned, 20% water loss @ 60'. Hole filled w/grout, while grouting 0+10, 5U, 45°. Drilled 65'-80': 10-20% water loss, pressure tested & grouted. B.H. 80'.
0+10, ℄, 45°	Drilled 0-16'. Set 16', 2½" CSG. Drilled 16'-44': drilled into grout (0+22, ℄, 30°) @ 39', 100% water return from 0+22, ℄, 30°, plugged off 0+22, ℄, 30°, flow tested and grouted. Drilled 44'-73': 100% water loss @ 68', pressure tested & grouted. Drilled 73'-80': 100% water loss & 75', pressure tested & grouted. B.H. 80'.
0+7.5, ℄, 45°	Drilled 0-16'. Set 16', 2½" CSG. Drilled 16'-80': 10% water loss 16'-75', grout @ 22-23', 100% water loss @ 77', pressure tested & grouted. B.H. 80'.
0+05, ℄, 45°	Drilled 0-16'. Set 16', 2½" CSG. Drilled 16'-50': no water loss, pressure tested. Drilled 50'-80': slight water loss @ 55', 10% loss 58-80', pressure tested & grouted. B.H. 80'.

T-1E QUINTARY HOLES (Cont'd)

HOLE NO.	REMARKS
0+2.5, ℄, 45°	Drilled 0-16. Set 16', 2½" CSG. Drilled 16'-80': 10-20% water loss, grout @ 29', pressure tested & grouted. B.H. 80'.
0+00, ℄, 45°	Drilled 0-16', Set 16', 2½" CSG. Drilled 16'-42', 100% water loss @ 36', 90% return @ 38', pressure tested & grouted. Drilled 42'-69': 100% water loss @ 64', pressure tested & grouted. Drilled 69'-80': 80% water loss @ 76', pressure tested & grouted. B.H. 80'.
0+10, 5'U, 45°	Drilled 0-16'. Set 16', 2½" CSG. Drilled 16'-50': no water loss, pressure tested & grouted. Drilled 50'-68': 10% water loss @ 56', 100% water loss @ 63', pressure tested & grouted. Drilled 68'-80': 100% water loss @ 68', grouted. B.H. 80'.
0+15, 1.5U, 45°	Drilled 0-16'. Set 16', 3½" CSG. Drilled 16'-41': 100% water loss @ 20'-23', @ 23'-27' water returned out of 0+20, ℄, 30° (grout settled), 37'-39' soft, 100% water loss @ 37', pressure tested & grouted. Redrilled 0-41': 50% water loss, pressure tested & grouted. Drilled 41'-59': 100% water loss @ 55', pressure tested & grouted. Drilled 59'-80': 100% water loss @ 74' pressure tested & grouted. B.H. 80'.
0+15, 5'U, 45°	Drilled 0-16'. Set 16', 2½" CSG. Drilled 16'-42': 100% water loss @ 38', packer couldn't get past 23'. Redrilled 23'-42': pressure tested, flow tested & grouted. Drilled 42'-50': 100% water loss @ 43'-44', red sand caving into hole, pressure tested & grouted. Drilled 50'-57': some water loss @ 50.5', 100% water loss @ 52'. Red sand. Wick. Backfilled hole.

TABLE T - 2 PRESSURE TEST RECORD

T-2A PRIMARY HOLES

HOLE NO.	DATE TESTED	INTERVAL TESTED	DEPTH CASING	DEPTH PACKER	BOTTOM HOLE	GAGE PRESS.	WATER TAKE CF/MIN	REMARKS
0+40, ℄, V	7 Oct 78	55'-80'	20'	55'	80'	25#	0	
0+40, ℄, V	7 Oct 78	40'-80'	20'	40'	80'	3#	1.2	Water take 40'-55'.
0+20, ℄, V	28 Sept 78	55'-80'	-	55'	80'	0	1.2	
0+00, ℄, V	28 Sept 78	50'-80'	-	50'	80'	15#	0.7	W.L. 55'.
-(0+20), ℄, V	28 Sept 78	55'-80'	-	55'	80'	-	0	
-(0+20), ℄, V	28 Sept 78	35'-80'	-	35'	80'	0	1.0	Water Take 35'-55'.
-(0+40), ℄, V	27 Sept 78	35'-80'	-	35'	80'	18#	0	Could not set packer @ 50' or 15'
-(0+40), ℄, V	27 Sept 78	20'-80'	-	20'	80'	10#	0	
-(0+60), ℄, V	27 Sept 78	65'-80'	-	65'	80'	30#	0.3	
-(0+60), ℄, V	27 Sept 78	55'-80'	-	55'	80'	28#	0.0	
-(0+60), ℄, V	27 Sept 78	35'-80'	-	35'	80'	18#	0.0	
-(0+60), ℄, V	27 Sept 78	20'-80'	-	20'	80'	10#	0.3	
-(0+80), ℄, V	27 Sept 78	55'-70'	-	55'	70'	28#	0.1	
-(0+80), ℄, V	27 Sept 78	35'-70'	-	35'	70'	18#	0.0	
-(0+80), ℄, V	27 Sept. 78	15'-70'	-	15'	70'	8#	0.0	Broken rock @ surface, no test @ 0'
0+50, ℄, V	14 Nov 78	31'-50'	31'	0	50'	2#	0.1	

T-2B SECONDARY HOLES

HOLE NO.	DATE TESTED	INTERVAL TESTED	DEPTH CASING	DEPTH PACKER	BOTTOM HOLE	GAGE PRESS.	WATER TAKE CF/MIN	REMARKS
0+28, ℄, V	24 Oct 78	10'-35'	10'	0	35'	0	1.3	Stage I
0+28, ℄, V	14 Nov 78	35'-60'	10'	0	60'	5#	0.1	Stage II
0+10, ℄, V	24 Oct 78	10'-35'	10'	0	35'	0	1.3	Stage I
0+10, ℄, V	14 Nov 78	35'-60'	10'	0	60'	4#	1.7	Stage II
-(0+10), ℄, V	24 Oct 78	4'-35'	-	4'	35'	0	1.3	Stage I
-(0+10), ℄, V	14 Nov 78	35'-60'	-	0	60'	0	1.5	Stage II
-(0+30), ℄, V	24 Oct 78	3'-35'	-	3'	35'	0	1.3	Stage I
-(0+30), ℄, V	14 Nov 78	35-60	-	0	60'	0	1.2	Stage II
-(0+50), ℄, V	24 Oct 78	10'-35'	-	10'	35'	0	1.4	Stage I
-(0+50), ℄, V	14 Nov 78	35'-60'	-	0	60'	0	1.8	Stage II
-(0+70), ℄, V	24 Oct 78	10'-35'	-	10'	35'	2#	0.4	Stage I
-(0+70), ℄, V	14 Nov 78	35'-65'	-	0	65'	0	1.8	Stage II

T-2C TERTIARY HOLES

HOLE NO.	DATE TESTED	INTERVAL TESTED	DEPTH CASING	DEPTH PACKER	BOTTOM HOLE	GAGE PRESS.	WATER TAKE CF/MIN	REMARKS
-(0+65), ℄, 30°	12 Dec 78	0-35'	-	-	35'	3#	1.1	Stage I, 4' standpipe
-(0+65), ℄, 30°	13 Dec 78	35'-65'	-	-	65'	15#	0.2	Stage II, 4' standpipe
-(0+55), ℄, 30°	12 Dec 78	3'-35'	-	0	35'	3#	2.0	3' standpipe
-(0+56), ℄, 30°	13 Dec 78	0-65'	-	0	65'	3#	1.7	
-(0+45), ℄, 30°	9 Dec 78	0-35'	-	-	35'	0	2.0+	Stage I, 4' standpipe
-(0+45), ℄, 30°	12 Dec 78	35-65'	-	-	65'	15#	1.0	Stage II, 4' standpipe
-(0+35), ℄, 30°	6 Dec 78	0-35'	-	-	35'	2#	2.0	Stage I, 3' standpipe
-(0+35), ℄, 30°	12 Dec 78	35'-65'	3'	-	65'	15#	0.7	Stage II, 3' standpipe
-(0+25), ℄, 30°	17 Nov 78	0-35'	-	-	35'	0	1.8	Stage I
-(0+25), ℄, 30°	9 Dec 78	35'-65'	-	-	65'	18#	0.1	Stage II, 4' standpipe
-(0+15), ℄, 30°	17 Nov 78	0-35'	-	0	35'	0	1.8	Stage I
-(0+15), ℄, 30°	11 Dec 78	35'-65'	-	0	65'	15#	1.5	Stage II
-(0+05), ℄, 30°	29 Nov 78	0-35'	-	0	35'	0	1.8	Stage I
-(0+05), ℄, 30°	12 Dec 78	35'-65'	-	0	65'	0	2.0	Stage II
0+05, ℄, 30°	4 Dec 78	0-35'	-	0	35'	0	1.8	Stage I
0+05, ℄, 30°	11 Dec 78	35'-65'	-	0	65'	0	2.0	Stage II

T-2C TERTIARY HOLES

HOLE NO.	DATE TESTED	INTERVAL TESTED	DEPTH CASING	DEPTH PACKER	BOTTOM HOLE	GAGE PRESS.	WATER TAKE CF/MIN	REMARKS
0+15, ℄, 30°	2 Dec 78	0-35'	-	0	35'	0	1.8	Stage I
0+15, ℄, 30°	9 Dec 78	35'-65'	-	0	65'	15#	1.5	Stage II
0+24, ℄, 25°	17 Nov 78	20'-65'	-	20'	65'	0	1.8	could not set packer @ 45'
-(0+2.5), ℄, V	4 Nov 78	0-35'	-	0	35'	0	1.3	W.L. 10' @ ½ hr. after testing
0+2.5, ℄, V	4 Nov. 78	0-35'	-	0	35'	0	1.3	

T-2D QUATERNARY HOLES

HOLE NO.	DATE TESTED	INTERVAL TESTED	DEPTH CASING	DEPTH PACKER	BOTTOM HOLE	GAGE PRESS.	WATER TAKE CF/MIN	REMARKS
-(0+60), 1.5U, 30°	16 Dec 78	0-35'	-	-	35'	3#	2.0	Stage I, 4' standpipe
-(0+60), 1.5U, 30°	18 Dec 78	35-65'	-	0	65'	15#	0.1	Stage II
-(0+50), 1.5U, 30°	16 Dec 78	0-35'	-	-	35'	3#	2.0	Stage I, 4' standpipe
-(0+50), 1.5U, 30°	18 Dec 78	35'-65'	-	0	65'	15#	0.8	Stage II
-(0+40), 1.5U, 30°	16 Dec 78	0-35'	-	-	35	3#	1.8	Stage I, 4' standpipe
-(0+40), 1.5U, 30°	10 Jan 79	35'65'	-	0	65'	0	1.8	Stage II, W.L. 53'
-(0+30), 1.5U, 30°	15 Dec 78	0-35'	-	-	35'	3#	1.7	Stage I, 4' standpipe
-(0+30), 1.5U, 30°	10 Jan 79	35'-65'	-	0	65'	0	1.8	Stage II
-(0+20), 1.5U, 30°	15 Dec 78	0-35'	-	-	35'	3#	1.5	Stage I, 4' standpipe
-(0+20), 1.5U, 30°	10 Jan 79	35'-65'	-	0	65'	15#	0	Stage II
-(0+10), 1.5U, 30°	15 Dec 78	0-35'	-	-	35'	3#	2.2	Stage I, 4' standpipe
-(0+10), 1.5U, 30°	10 Jan 79	35'-65'	-	0	65'	15#	0.5	Stage II
0+00, 1.5U, 30°	15 Dec 78	0-35'	-	-	35'	3#	2.2	Stage I, 4' standpipe
0+00, 1.5U, 30°	10 Jan 79	35'-65'	-	0	65'	15#	0.05	Stage II
0+10, 1.5U, 30°	13 Dec 78	0-35'	-	-	35'	3#	1.0	Stage I
0+10, 1.5U, 30°	10 Jan 79	35'-65'	-	0	65'	0	1.8	Stage II, W.L. 50'

T2-D QUATERNARY HOLES

HOLE NO.	DATE TESTED	INTERVAL TESTED	DEPTH CASING	DEPTH PACKER	BOTTOM HOLE	GAGE PRESS.	WATER TAKE CF/MIN	REMARKS
0+20, 1.5U, 30°	14 Dec 78	0-35'	-	-	35'	3#	2.0+	Stage I
0+20, 1.5U, 30°	10 Jan 79	35'-65'	-	0	65'	0	1.8	Stage II, W.L. 58'

T2-E QUINTARY HOLES

HOLE NO.	DATE TESTED	INTERVAL TESTED	DEPTH CASING	DEPTH PACKER	BOTTOM HOLE	GAGE PRESS.	WATER TAKE CF/MIN	REMARKS
0+50, 2.5U, V	18 Jan 79	26'-35'	26'	-	35'	-	-	Charged 2" CSG, w/water. W.L. dropped 1 foot/min.
-(0+25), ℄, 30°	18 Jan 79	13'-40'	13'	-	40'	3#	0.01	3' standpipe
0+25, ℄, 30°	18 Jan 79	13'-40'	13'	-	40'	5#	0.02	3' standpipe
0+15, 1.5U, 45°	17 Jan 79	35-41'	16'	35'	41'	0	1.6	Stage I, Grouted & Re-tested
0+15, 1.5U, 45°	17 Jan 79	35-41'	16'	35'	41'	-	0.3	Stage I
0+15, 1.5U, 45°	19 Jan 79	50'-59'	16'	50'	59'	0	2.0	Stage II
0+15, 1.5U, 45°	20 Jan 79	62'-80'	16'	62'	80'	0	2.2	Stage III
0+17.5, ℄, 30°	18 Nov. 79	13'-40'	13'	-	40'	5#	0.5	Stage I, 3' standpipe
0+17.5, ℄, 30°	18 Nov 79	30-40'	13'	30'	40'	5#	0.4	Stage I, 3' standpipe
0+17.5, ℄, 30°	18 Nov 79	20'-40'	13'	20'	40'	5#	0.55	Stage I, 3' standpipe
0+17.5, ℄, 30°	23 Nov 79	40'-65'	13'	0	65'	5#	0.05	Stage II
0+22, ℄, 30°	18 Jan 79	13'-40'	13'	-	40'	0	1.5	Stage I, 3' standpipe
0+22, ℄, 30°	18 Jan 79	30'-40'	13'	0	40'	0	1.5	Stage I, 3' standpipe
0+22, ℄, 30°	18 Jan 79	35'-40'	13'	35'	40'	0	1.5	Stage I, 3' standpipe
0+22, ℄, 30°	20 Jan 79	13'-40'	13'	40'	67'	-	0.1	Stage II, Flow test
0+22, ℄, 30°	23 Jan 79	40'-67'	13'	40'	67'	0	2.0	Stage II, Couldn't get packer past 42'

T2-E QUINTARY HOLES

HOLE NO.	DATE TESTED	INTERVAL TESTED	DEPTH CASING	DEPTH PACKER	BOTTOM HOLE	GAGE PRESS.	WATER TAKE CF/MIN	REMARKS
0+15, 5U, 45°	25 Jan 79	35'-42'	16'	35'	42'	0	1.8+	Stage I
0+15, 5U, 45°	26 Jan 79	16'-35'	16'	35'	42'	-	0.35	State I, Flow test
0+10, ℄, 45°	26 Jan 79	16'-35'	16'	35'	44'	-	0.15	Stage I, Flow test
0+10, ℄, 45°	30 Jan 79	50'-73'	16'	50'	73'	0	1.8	Stage II
0+10, ℄, 45°	31 Jan 79	65'-80'	16'	65'	80'	-	0.5	Stage III, Anticipated larger water take
0+00, ℄, 45°	26 Jan 79	30'-42'	16'	30'	42'	0	1.8	Stage I
0+00, ℄, 45°	30 Jan 79	50'-69'	16'	50'	69'	0	1.8	Stage II
0+00, ℄, 45°	1 Feb 79	69'-80'	16'	35'	80'	0	1.8	Stage III
0+05, ℄, 45°	3 Feb 79	16'-50'	16'	0	50'	5#	0.1	
0+05, ℄, 45°	5 Feb 79	50'-80'	16'	50'	80'	8#	1.3	
0+10, 5U, 45°	5 Feb 79	16'-50'	16'	0	50'	2#	1.5	Stage I
0+10, 5U, 45°	5 Feb 79	35'-50'	16'	35'	50'	10#	1.3	Stage I
0+10, 5U, 45°	6 Feb 79	50'-68'	16'	50'	68'	0	1.8	Stage II
0+7.5, ℄, 45°	8 Feb 79	50'-80'	16'	50'	80'	5#	0.2	
0+15, ℄, 45°	1 Feb 79	35'-50'	16'	35'	50'	0	1.8	Stage I
0+15, ℄, 45°	3 Feb 79	50'-65'	16'	0	65'	5#	1.1	Stage II
0+15, ℄, 45°	5 Feb 79	49'-65'	16'	49'	65'	15#	1.8	Stage II, Couldn't set packer @ 55'

T-2E QUINTARY HOLES CONT.

HOLE NO.	DATE TESTED	INTERVAL TESTED	DEPTH CASING	DEPTH PACKER	BOTTOM HOLE	GAGE PRESS.	WATER TAKE CF/MIN	REMARKS
0+15, ℄, 45°	6 Feb 79	65'-72'	16'	50'	72'	0	1.8	Stage III
0+15, ℄, 45°	9 Feb 79	72'-80'	16'	0	80'	3#	0.7	Stage IV
0+12.5, ℄, 45°	3 Feb 79	16'-50'	16'	0	50'	5#	0.1	
0+12.5, ℄, 45°	10 Feb 79	50'-80'	16'	50'	80'	10#	1.1	
0+2.5, ℄, 45°	9 Feb 79	16'-50'	16'	0	50'	5#	0.1	
0+2.5, ℄, 45°	10 Feb 79	50'-80'	16'	50'	80'	10#	1.4	

TABLE T - 3 GROUTING RECORD

T-3A PRIMARY HOLES

HOLE NO.	DATE BEGAN GROUTING	INTERVAL GROUTED	DEPTH CASING	DEPTH PACKER	BOTTON HOLE	GAGE PRESSURE	GROUT MIX	SACKS/LBS/OF CEMENT/BENT/SAND	INTERVAL OF GROUT TAKE	REMARKS
0+40, ℄, V	29 Sept 78	0-50'	-	-	50'	-	1:1-0.8:1	52/100/0	-	Hole backfilled to fill "voids' in embankment caused by drilling.
0+40, ℄, V	9 Oct 78	40'-80'	20'	40'	80'	10-12#	3:1-2:1	16/0/0	40'-55'	
0+40, ℄, V	10 Oct 78	20'-40'	20'	18'	80'	0-5#	3:1-1:1	89/100/0	20'-40'	
0+20, ℄, V	2 Oct 78	55'-80'	-	55'	80'	0-24#	3:1-0.8:1	99/0/0	55'-80'	Grout above packer, pumped 43 sacks prior to pressure drop.
0+20, ℄, V	10 Oct 78	35'-55'	-	35'	80'	15#	3:1	3/0/0	35'-55'	
0+20, ℄, V	10 Oct 78	15'-35'	-	15'	80'	0	3:1-0.9:1	231/1050/0	27'-35'	
0+20, ℄, V	11 Oct 78	15'-35'	-	15'	80'	0	1:1-0.9:1	327/1450/0	15'-27'	G.L. 27' @ start. Grout above packer
0+20, ℄, V	12 Oct 78	3'15'	-	3'	80'	2#	3:1-2:1	4/0/0	3'15'	
0+00, ℄, V	12 Oct 78	35'-80'	-	35;	80'	15#	3:1-1:1	54/0/0	35'-55'	Poor set, packer raised to 25'
0+00, ℄, V	12 Oct 78	25'-80'	-	25'	80'	12#	0.9:1	71/0/0	25'-55'	Grout 7' above packer
0+00, ℄, V	13 Oct 78	15'-20'	-	15'	80'	0-5#	3:1-0.9:1	375/50/0	15'-20'	G.L. 20', grout 7' above packer
0+00, ℄, V	13 Oct 78	2'-15'	-	2'	80'	0	2:1-0.9:1	140/150/0	5'-15'	G.L. 8', G.L. 7', void 5'-7'

T-3A PRIMARY HOLES CONT.

HOLE NO.	DATE BEGAN GROUTING	INTERVAL GROUTED	DEPTH CASING	DEPTH PACKER	BOTTON HOLE	GAGE PRESSURE	GROUT MIX	SACKS/LBS/OF CEMENT/BENT/SAND	INTERVAL OF GROUT TAKE	REMARKS
0+00, ℄, V	16-18 Oct 78	0'-7'	-	-	80'	-	-	1987/2950/780	5'-7'	Materials poured from surface Much sand added w/o mixing. G.L. 5'3".
0+00, ℄,V	16 Dec 78	0-6'	-	-	80'	3#	3:1-1:1	141/550/100	0-6'	Grouting resumed after grouting adjacent holes. 4' standpipe
-(0+20), ℄, V	16 Oct 78	15'-80'	-	15'	80'	7#	3:1	3/0/0	15'-55'	Removed packerr, grout @ surface.
-(0+80), ℄, V	27 Sept 78	0-70'	-	0	70'	2-3#	3:1	0/0/0	-	

T-3B SECONDARY HOLES

HOLE NO.	DATE BEGAN GROUTING	INTERVAL GROUTED	DEPTH CASING	DEPTH PACKER	BOTTON HOLE	GAGE PRESSURE	GROUT MIX	SACKS/LBS/OF CEMENT/BENT/SAND	INTERVAL OF GROUT TAKE	REMARKS
0+28, ℄, V	31 Oct 78	10'-35'	10'	0	35'	0	3:1-1:1	141/400/84	10'-35'	G.L. 28.5'
0+28, ℄, V	1 Nov 78	10'-35'	10'	0	35'	0	3:1-1:1	150/500/110	10'-28.5'	G.L. 25'
0+28, ℄, V	2 Nov 78	10'-35'	10'	0	35'	4-5#	3:1-2:1	37/100/0	10'-25'	Hole Influenced by grouting on 0+10, ℄, , V, G.L. 15'
0+28, ℄, V	3 Nov 78	10'-35'	10'	0	35'	5#	3:1-2:1	15/0/0	10'15'	
0+10, ℄, V	28-30 Oct 78	10'-35'	10'	0	35'	0	3:1-1:1	122/350/60	10'-35'	Stage I, G.L. 17'
0+10, ℄, V	30-31 Oct 78	10'-35'	10'	0	35'	0-5#	3:1-1:1	578/1800/389	10'-17'	Stage I, G.L. 12', void 11-12'
0+10, ℄, V	1-3 Nov 78	10'-35'	10'	0	35'	0-5#	3:1-1:1	497/550/390	10'-12'	Stage I, G.L. 11.5', G.L. 11'
0+10, ℄, V	14 Nov 78	35-60'	10'	0	60'	0-2#	3:1	5/0/0	35'-60'	Stage II
-(0+10), ℄, V	27 Oct 78	2-35'	-	2'	35'	0	3:1-0.8:1	105/0/0	2-35'	Stage I, G.L. 13'
-(0+10), ℄, V	27 Oct 78	2-35'	-	2'	35'	0	0.8:1	184/0/90	2-13'	Stage I, G.L. 13'
-(0+10), ℄, V	28 Oct 78	2-35'	-	2'	35'	0	3:1-1:1	98/300/45	2-13'	Stage I
-(0+10), ℄, V	14 Nov 78	35-60'	-	0'	60'	0-2#	3:1-2:1	19/12/0	35-65'	Stage II
-(0+30), ℄, V	26 Oct 78	0-35'	-	0	35'	0-5#	3:1-1:1	80/50/3	0-35'	Stage I
-(0+30), ℄, V	14 Nov 78	35-60'	-	0	60'	0-15#	3:1	12/0/0	35-60'	Stage II

T-3B SECONDARY HOLES CONT.

HOLE NO.	DATE BEGAN GROUTING	INTERVAL GROUTED	DEPTH CASING	DEPTH PACKER	BOTTON HOLE	GAGE PRESSURE	GROUT MIX	SACKS/LBS/OF CEMENT/BENT/SAND	INTERVAL OF GROUT TAKE	REMARKS
-(0+50), ℄, V	25 Oct 78	3'-35'	-	3'	35'	0	3:1-0.8:1	523/0/0	3'-35'	Stage II, Connection w/(0+30), ℄, , v:G.L. 30', G.L. 28'
-(0+50), ℄, V	26 Oct 78	3-35'	-	3'	35'	0-3#	3:1	152/200/55	3'-28'	Stage II
-(0+50), ℄, V	15 Nov 78	35'-60'	-	0	60'	0-15#	3:1-1.5:1	73/100/0	35'-60'	Stage II
-(0+70), ℄, V	25 Oct 78	4'-35'	-	4'	35'	0-3#	4:1-3:1	2/0/0	4'-35'	Stage I
-(0+70), ℄, V	14 Nov 78	35-60'	-	0	65'	0-15#	3:1-1:1	122/250/0	35'-65'	Stage II

T3-C TERTIARY HOLES

HOLE NO.	DATE BEGAN GROUTING	INTERVAL GROUTED	DEPTH CASING	DEPTH PACKER	BOTTON HOLE	GAGE PRESSURE	GROUT MIX	SACKS/LBS/OF CEMENT/BENT/SAND	INTERVAL OF GROUT TAKE	REMARKS
0+2.5, ℄, V	4 Nov 78	0-35'	-	0	35'	0	3:1-1:1	347/1050/276	0-35'	G.L. 17', W.L. @ 16' in -(0+2.5), ℄, V
0+2.5, ℄, V	6 Nov 78	0-35'	-	0	35'	0	3:1-1:1	209/650/163	0-17'	G.L. 14.5', W.L. @ 25' in -(0+2.5), ℄, V
0+2.5, ℄, V	7 Nov 78	0-35'	-	0	35'	0	3:1-1:1	405/1200/331	0-14.5'	G.L. 14'
0+2.5, ℄, V	8 Nov 78	0-35'	-	0	35'	0	3:1-1:1	126/350/104	0-14'	G.L. 13'
0+2.5, ℄, V	8 Nov 78	0-35'	-	0	35'	0-2#	3:1-1:1	131/400/108	0-13'	
-(0+2.5), ℄, V	8 Nov 78	0-35'	-	0	35'	0	3:1	2/0/0	0-10'	W.L. 10' @ ½ hr. after pressure test. Grout from 02.5, ℄, V appears to have sealed zone of water take
0+24, ℄, 25°	17 Nov - 1 Dec 78	20'-65'	-	20'	65'	0-8#	3:1-1:1	1030/2675/314	20'-65'	Grout above packer
0+15, ℄, 30°	2-4 Dec 78	0-35'	-	0	35'	0	3:1-1:1	143/350/12	0-35'	Stage I, grout above packer
0+15, ℄, 30°	9 Dec 78	35'-65'	-	-	65'	3-17#	3:1-1:1	126/550/11	35'-65'	Stage II, 4' standpipe
0+05, ℄, 30°	4 Dec 78	0-35'	-	0	35'	0	1:1	93/200/43	0-35'	Stage I
0+05, ℄, 30°	11 Dec 78	35'-65'	-	0	65'	0-18#	3:1-1.5:1	76/200/0	35-65'	Stage II
-(0+05), ℄, 30°	29 Nov 78	0-35'	-	0	35'	1#	3:1	3/0/0	0-35'	Stage I

T-3C TERTIARY HOLES CONT.

HOLE NO.	DATE BEGAN GROUTING	INTERVAL GROUTED	DEPTH CASING	DEPTH PACKER	BOTTON HOLE	GAGE PRESSURE	GROUT MIX	SACKS/LBS/OF CEMENT/BENT/SAND	INTERVAL OF GROUT TAKE	REMARKS
-(0+05), ℄, 30°	12 Dec 78	35'-65'	-	0	65'	0-18#	3:1-1:1	110/325/0	35'-65'	Stage II
-(0+15), ℄, 30°	29 Nov 78	0-35'	-	0	35'	0	3:1	8/0/0	0-35'	Stage I
-(0+15), ℄, 30°	11 Dec 78	35'-65'	-	0	65'	17-18#	3:1	6/0/0	35'-65'	Stage II
-(0+25), ℄, 30°	29 Nov - 5 Dec 78	0-35'	-	0	35'	0	3:1-0.9:1	1321/3675/826	0-35'	State I, G.L. 25'
-(0+25), ℄, 30°	6-7 Dec 78	0-35'	-	-	35'	3#	3:1-1:1	149/400/110	0-25;	Stage I, 4' standpipe, G.L. 22'
-(0+25), ℄, 30°	9 Dec 78	0-35'	-	-	35'	3-10#	3:1-1:1	80/30/40	0-22;	Stage I, 4' standpipe
-(0+35), ℄, 30°	6 Dec 78	9-35'	-	-	35'	2#	3:1-1:1	124/250/62	0-35'	Stage I, 3' standpipe, grout coming out -(0+30), ℄, V, G.L. 3'
-(0+35), ℄, 30°	12 Dec 78	35-65'	-	-	65'	15#	3:1	5/0/0	35-65'	Stage II, 3' standpipe
-(0+45), ℄, 30°	9 Dec 78	0-35'	-	-	35'	3-5#	3:1-1:1	51/150/6	0-35'	Stage I, 4' standpipe
-(0+45), ℄, 30°	12 Dec 78	35-65'	-	-	65'	18#	3:1	3/0/0	35-65'	Stage II, 4' standpipe
-(0+55), ℄, 30°	12 Dec 78	0-35'	-	-	35'	3#	3:1	6/0/0	0-35'	4' standpipe
-(0+56), ℄, 30°	13 Dec 78	0-65'	-	0	65'	15-18#	3:1	9/20/0	0-65'	grout coming out -(0+55), ℄, 30°
-(0+65), ℄, 30°	12 Dec 78	0-35'	-	-	35'	3#	3:1	2/0/0	0-35'	Stage I, 4; standpipe

T-3D QUATERNARY HOLES

HOLE NO.	DATE BEGAN GROUTING	INTERVAL GROUTED	DEPTH CASING	DEPTH PACKER	BOTTON HOLE	GAGE PRESSURE	GROUT MIX	SACKS/LBS/OF CEMENT/BENT/SAND	INTERVAL OF GROUT TAKE	REMARKS
0+20, 1.5U, 30°	14-15 Dec 78	0-35'	-	-	35'	3-4#	3:1-1:1	106/400/21	0-35'	Stage I, 3-4' standpipe
0+20, 1.5U, 30°	10 Jan 79	35'-65'	-	0	65'	0-5#	5:1-1:1	70/261/0	35'-58'	Stage II
0+10, 1.5U, 30°	13 Dec 78	0-35'	-	-	35'	3#	3:1	9/0/0	0-35'	Stage I, 4' standpipe, grout came out -(0+15), ℄, 30°
0+10, 1.5U, 30°	10 Jan 79	35'-65'	-	0	65'	0-15#	5:1	4/16/0	35'-50'	Stage II
0+00, 1.5U, 30°	15 Dec 78	0-35'	-	-	35'	3-5#	3:1-1:1	104/400/53	0-35'	Stage I, 4' standpipe
-(0+10), 1.5U, 30°	15 Dec 78	0-35'	-	-	35'	3#	3:1	11/30/0	0-35;	Stage I, 4' standpipe
-(0+10), 1.5U, 30°	10 Jan 79	35'-65'	-	0	65'	15#	5:1	1/4/0	35-65'	Stage II
-(0+20), 1.5U, 30°	15 Dec 78	0-35'	-	-	35'	3#		7/30/0	0-35'	Stage I, 4' standpipe
-(0+30), 1.5U, 30°	15 Dec 78	0-35'	-	-	35'	3#		5/20/0	0-35'	Stage I, 4' standpipe
-(0+30), 1.5U, 30°	10 Jan 79	35'-65'	-	0	65'	15#		1/4/0	35'-65'	Stage II
-(0+40), 1.5U, 30°	16 Dec 78	0-35'	-	-	35'	5#		3/15/0	0-35'	Stage I, 4' standpipe
-(0+40), 1.5U, 30°	10 Jan 79	35-65;	-	0	65'	8-18#		30/156/0	35'-53'	Stage II
-(0+50), 1.5U, 30°	16 Dec 78	0-35'	-	-	35'	5#		3/15/0	0-35'	Stage I, 4' standpipe
-(0+50), 1.5U, 30°	18 Dec 78	35'-65'	-	0	65'	15#		1/8/0	35'-65'	Stage II
-(0+60), 1.5U, 30°	16 Dec 78	0-35'	-	-	35'	3-5#		2/15/0	0-35'	Stage I, 4' standpipe

T-3E QUINTARY HOLES

HOLE NO.	DATE BEGAN GROUTING	INTERVAL GROUTED	DEPTH CASING	DEPTH PACKER	BOTTON HOLE	GAGE PRESSURE	GROUT MIX	SACKS/LBS/OF CEMENT/BENT/SAND	INTERVAL OF GROUT TAKE	REMARKS
0+22, ℄, 30°	18 Nov 79	35'-40'	13'	35'	40'	10#	5:1	0/0/0	-	Stage I
0+22, ℄, 30°	18 Nov 79	13'-35'	13'	0	40'	5#	5:1	2/8/0	13'-35'	Stage I
0+22, ℄, 30°	23 Jan 79	40'-67'	13'	40'	67'	0-5#	5:1-3:1	26/100/0	40'-67'	Stage II
0+17.5, ℄, 30°	18 Nov 79	13'-40'	13'	0	40'	5#	5:1	2/8/0	13'-40'	
0+15, ℄, 45°	1 Feb 79	35'-50'	16'	35'	50'	0-10#	5:1	3/12/0	35'-50'	Stage I
0+15, ℄, 45°	5 Feb 79	49'-65'	16'	49'	65'	0-15#	5:1-2:1	18/80/0	49'-65'	Stage II
0+15, ℄, 45°	6 Feb 79	50'-72'	16'	50'	72'	0-20#	5:1-2:1	38/150/0	65'-72'	Stage III
0+15, ℄, 45°	9 Feb 79	72'-80'	16'	0	80'	4#	5:1	3/12/0	72'-80'	Stage IV
0+12.5, ℄, 45°	10 Feb 79	50'-80'	16'	50'	80'	0-15#	5:1	4/16/0	50'-80'	
0+10, ℄, 45°	26 Jan 79	16'-44'	16'	0	44'	4#	5:1-3:1	2/8/0	16'-44'	Stage I
0+10, ℄, 45°	30 Jan 79	50'-73'	16'	50'	73'	0-15#	5:1-3:1	10/40/0	50'-73'	Stage II
0+10, ℄, 45°	31 Jan 79	44'-50' & 73'-80'	16'	-	80'	0-20#	5:1-1:1	112/350/0	73'-80'	Stage III, grouted through rods @ 77'
0+7.5, ℄, 45°	9 Feb 79	16'-80'	16'	-	80'	0-35#	5:1-1:1	107/450/0	16'-80'	Grouted thru rods
0+05, ℄, 45°	5 Feb 79	50'-80'	16'	50'	80'	0-20#	5:1-1:1	33/150/0	50'-80'	
0+2.5, ℄, 45°	10 Feb 79	50'-80'	16'	50'	80'	0-15#	5:1-3:1	9/31/0	50'-80'	

T-3E QUINTARY HOLES CONT.

HOLE NO.	DATE BEGAN GROUTING	INTERVAL GROUTED	DEPTH CASING	DEPTH PACKER	BOTTON HOLE	GAGE PRESSURE	GROUT MIX	SACKS/LBS/OF CEMENT/BENT/SAND	INTERVAL OF GROUT TAKE	REMARKS
0+00, ℄, 45°	26 Jan 79	30'-42'	16'	30'	42'	4-8#	5:1	3/12/0	30'-42'	Stage I
0+00, ℄, 45°	26 Jan 79	16'-30'	16'	0	42'	4#	5:1	2/8/0	16'-30'	Stage I
0+00, ℄, 45°	30 Jan 79	50'-69'	16'	50'	69'	0-15#	5:1	4/16/0	50'-69'	Stage II
0+00, ℄, 45°	1 Feb 79	30'-50' & 69'-80'	16'	35'	80'	0-15#	5:1	5/20/0	69'-80'	Stage III
0+15, 1.5U, 45°	17 Jan 79	35'-41'	16'	35'	41'	0-10#	5:1-1:1	39/150/9	35'-41'	Stage I
0+15, 1.5U, 45°	18 Jan 79	16'-41'	16'	0	41'	-	5:1	3/12/0	16'-41'	Stage I, redrilled & regrouted
0+15, 1.5U, 45°	19 Jan 79	50'-59'	16'	50'	59'	0-15#	5:1-1:1	43/175/0	50'-59'	Stage II
0+15, 1.5U, 45°	20 Jan 79	62'-80'	16'	62'	80'	0-15#	5:1-1:1	57/200/0	62'-80'	Stage III, broke 2 packers trying to set @ 70'
0+15, 1.5U, 45°	20 Jan 79	16'-62'	16'	0	80'	8#	5:1	0/0/0	-	Stage III
0+15, 5U, 45°	25 Jan 79	35'-42'	16'	35'	42'	0-8#	5:1-0.8:1	175/550/0	35'-42'	Stage I
0+15, 5U, 45°	26 Jan 79	16'-35'	16'	0	42'	4#	3:1	1/4/0	16'-35'	Stage I
0+15, 5U, 45°	29 Jan 79	42'-50'	16'	-	50'	10-15#	5:1-1.5:1	42/150/0	42'-50'	Stage II, grouted through rods
0+10, 5U, 45°	5 Feb 79	35'-50'	16'	35'	50'	0-10#	5:1	3/12/0	35'-50'	Stage I, grout came out 0+12.5, ℄, , 45°
0+10, 5U, 45°	6 Feb 79	50'-68'	16'	50'	68'	10-20#	5:1-1:1	31/150/0	50'-68'	Stage II

T-3E QUINTARY HOLES CONT.

HOLE NO.	DATE BEGAN GROUTING	INTERVAL GROUTED	DEPTH CASING	DEPTH PACKER	BOTTON HOLE	GAGE PRESSURE	GROUT MIX	SACKS/LBS/OF CEMENT/BENT/SAND	INTERVAL OF GROUT TAKE	REMARKS
0+10, 5U, 45°	7 Feb 79	68'-80'	16'	-	80'	0-20#	5:1-2:1	37/150/0	68'-80'	Stage III, Grouted thru rods @ 76', G.L. 68'
0+10, 5U, 45°	7 Feb 79	16'-80'	16'	-	80'	0	5:1-1.5:1	42/150/0	16'-68'	Stage III, Grouted thru rods @ 63'

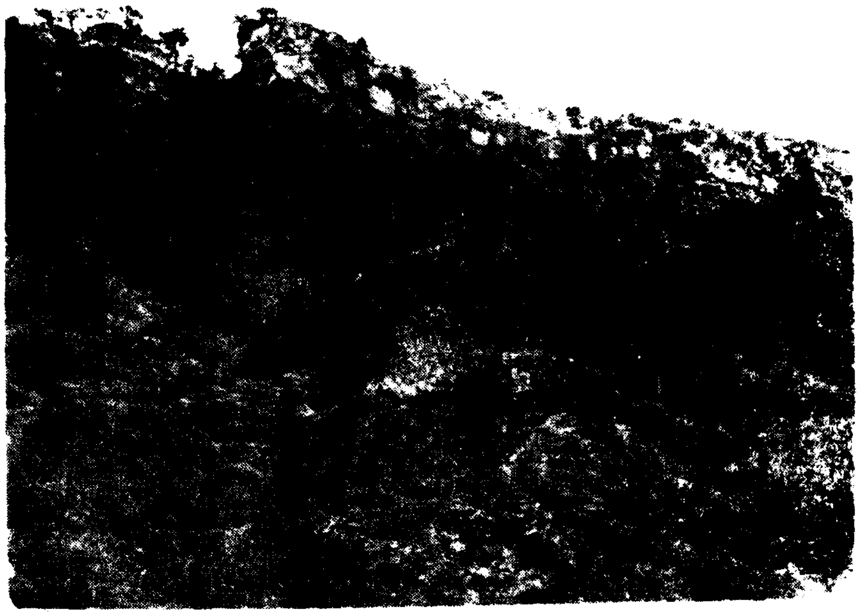


PHOTO NO. A-1: Geologic Formations found in Cold Brook Canyon. From top to bottom: Minnekahta (Limestone), Opeche (Shale and Sandstone), Minnelusa (Sandstone and Limestone)

PHOTO NO. A-2: The Minnekahta Formation downstream of the left abutment

PHOTO NO. A-3: The Minnekahta Limestone downstream from the left abutment.

PHOTO NO. A-4: Truck mounted mobile B-53 drill rig used to drill the grout holes.

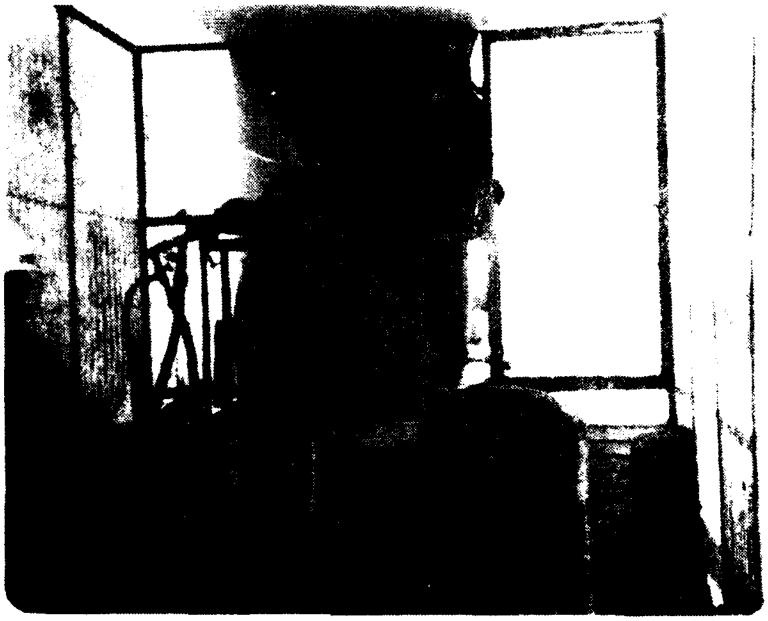


PHOTO NO. A-5: Grout Plant

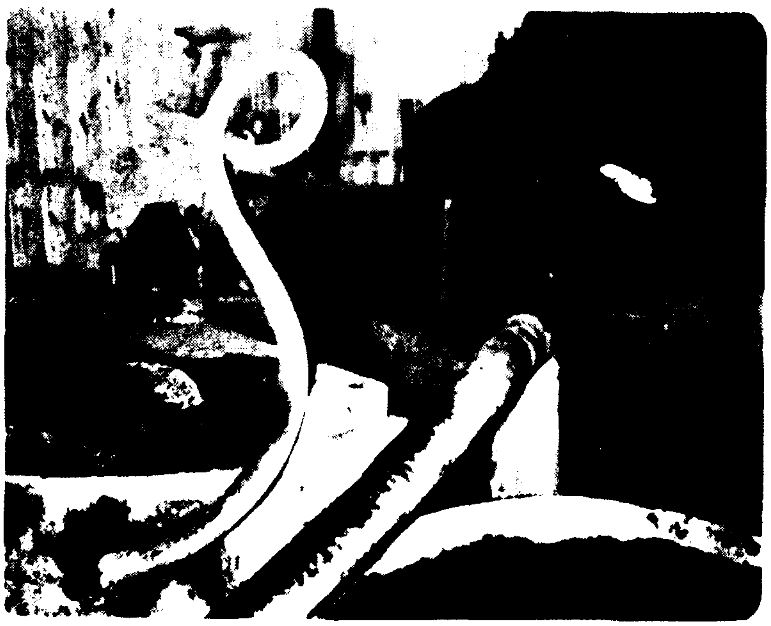
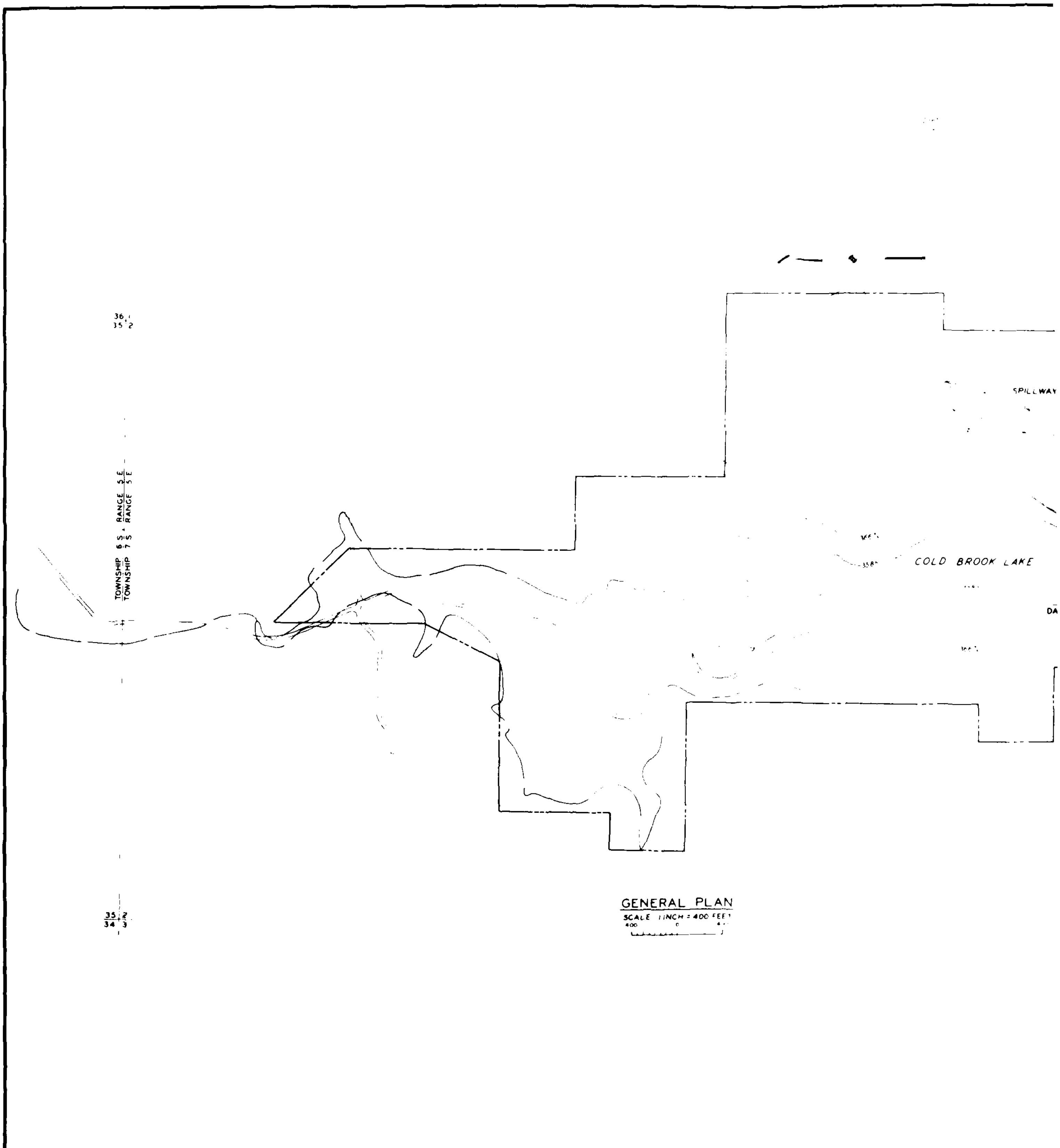
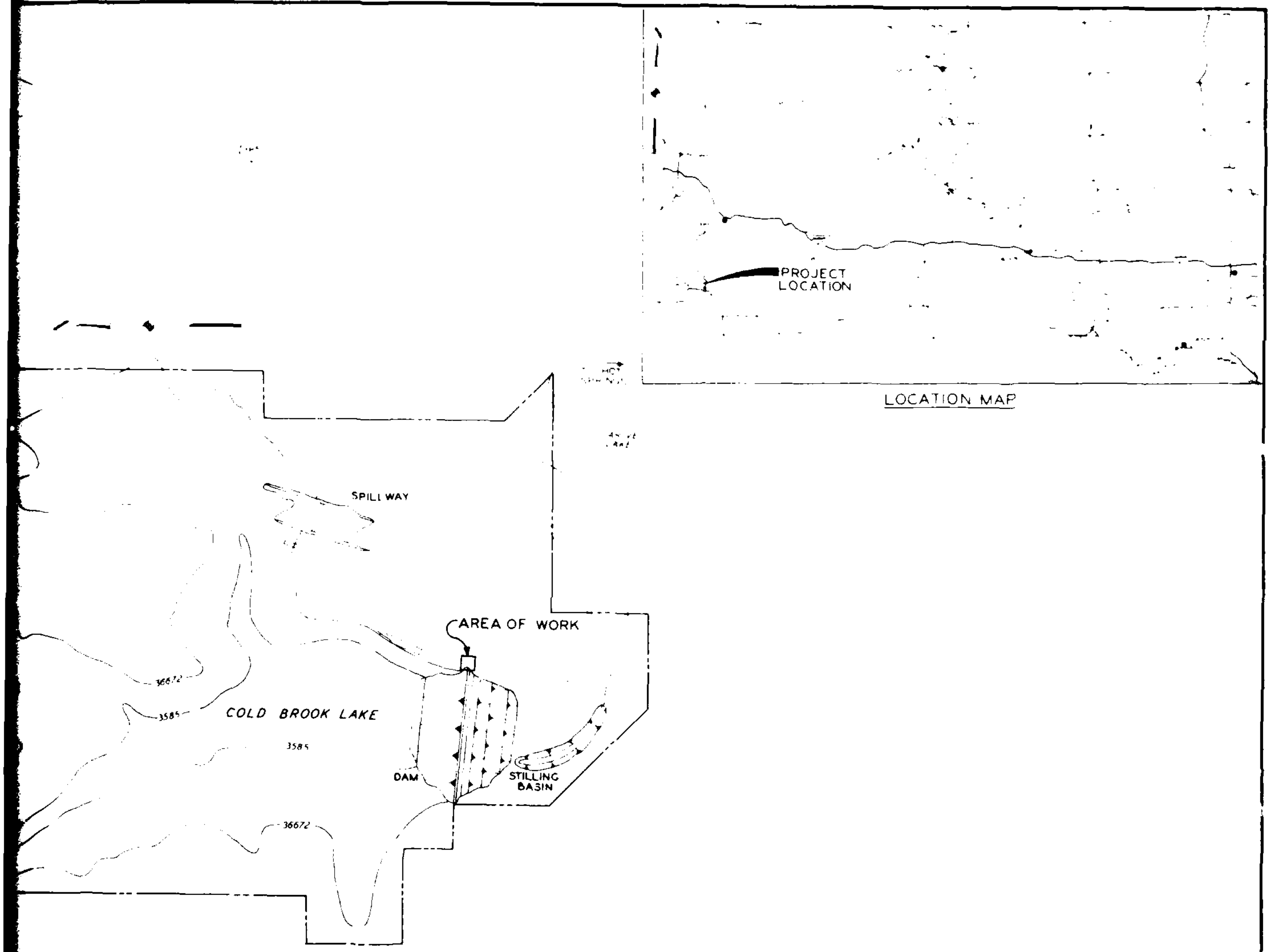


PHOTO NO. A-6: Agitating Sump

PHOTO NO. A-7: Water pressure test showing header, pressure gauge, packer inflation line and water meter.

PHOTO NO. A-8: Coil heater used to heat water.


36 | 1
35 | 2
TOWNSHIP 6 S. RANGE 5 E
TOWNSHIP 7 S. RANGE 5 E
SPILLWAY
COLD BROOK LAKE
GENERAL PLAN
SCALE 1 INCH = 400 FEET
35 | 2
34 | 3



U. S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS
OMAHA NEBRASKA

COLD BROOK DAM - HOT SPRINGS, SO DAK
EXTEND GROUT CURTAIN
LOCATION MAP & GENERAL PLAN

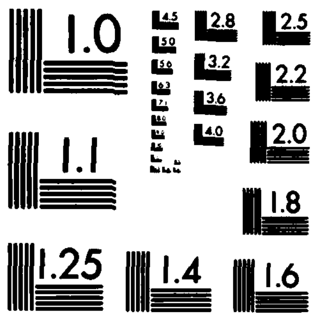
THIS PLAN ACCOMPANIES CONTRACT No
MODIFICATION NO

THINK VALUE ENGINEERING $$

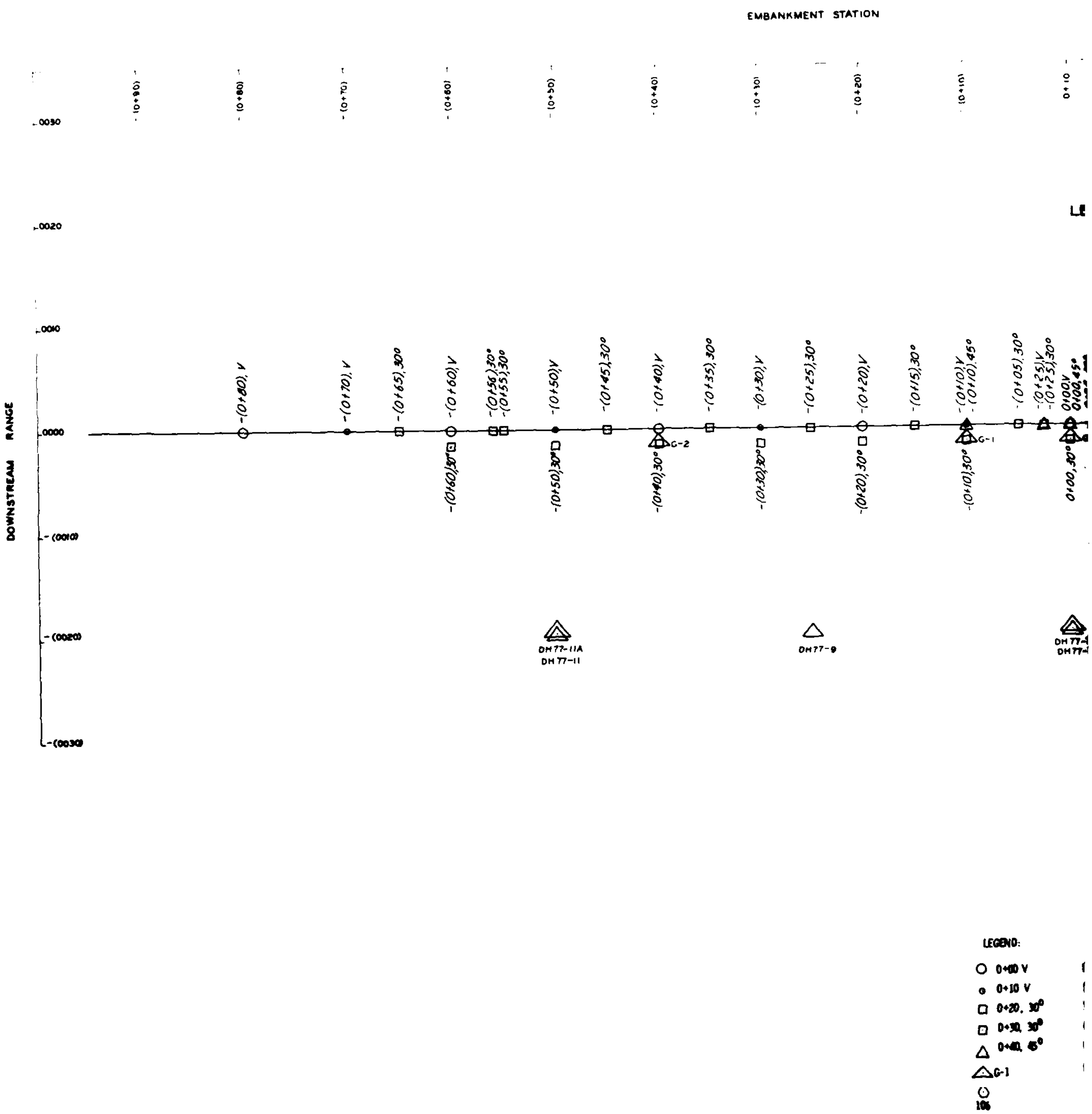
AD-A140 032 COLD BROOK DAM HOT SPRINGS SOUTH DAKOTA·FALL RIVER BASIN(U) ARMY ENGINEER DISTRICT OMAHA NE DEC 83 2/2

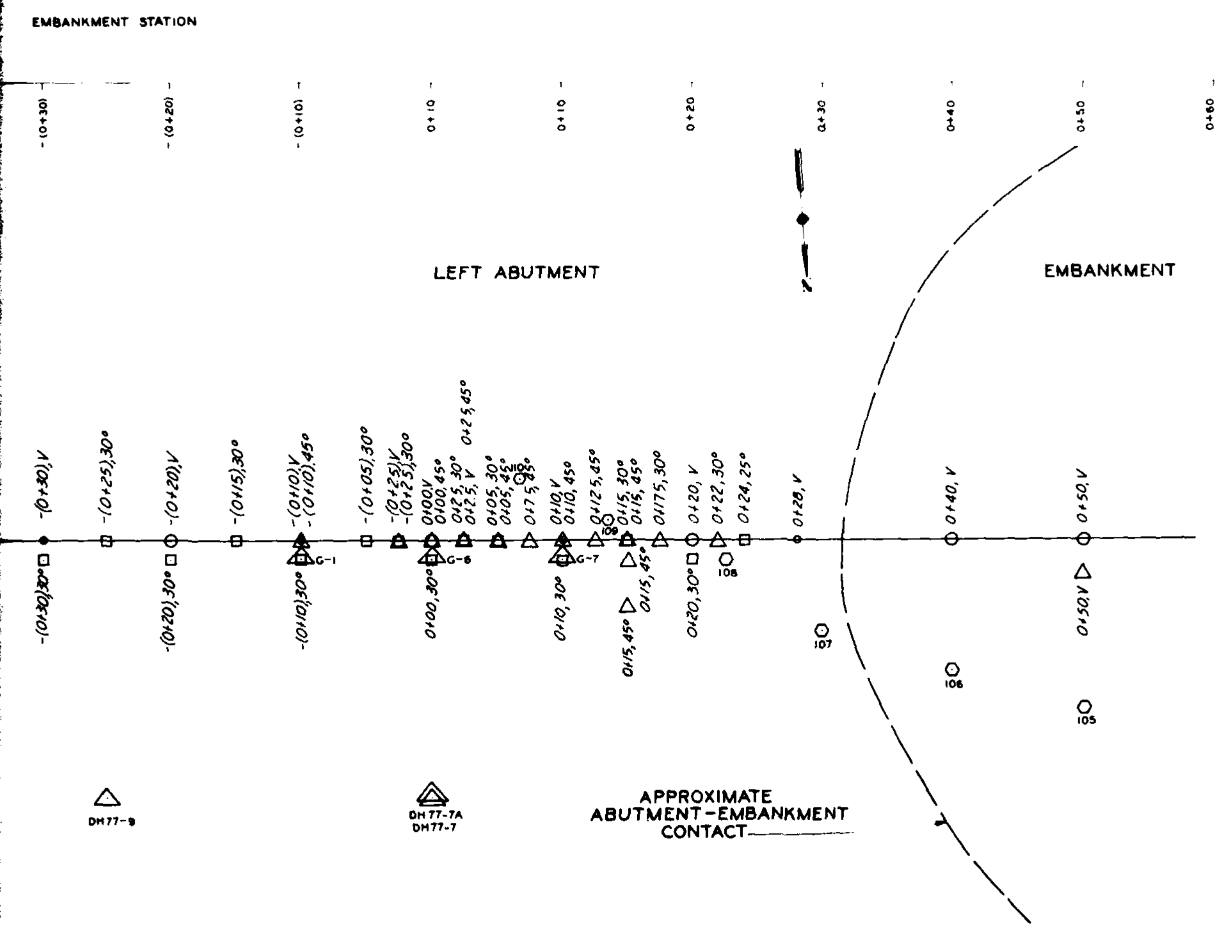
UNCLASSIFIED F/G 13/2 NL

END
DATE
FILMED
5 84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A


EMBANKMENT STATION
DOWNSTREAM RANGE
.0030
.0020
.0010
.0000
-(0010)
-(0020)
-(0030)
-(0+90)
-(0+80)
-(0+70)
-(0+60)
-(0+50)
-(0+40)
-(0+30)
-(0+20)
-(0+10)
0+10
DH77-11A
DH 77-11
DH77-9
LEGEND:
0+00 V
0+10 V
0+20, 30°
0+30, 30°
0+40, 45°
G-1



LEGEND:

○	0+00 V	Primary Grout Hole, Vertical
•	0+10 V	Secondary Grout Hole, Vertical
□	0+20, 30°	Tertiary Grout Hole, 30° Angle
⊡	0+30, 30°	Quaternary Grout Hole, 30° Angle
△	0+40, 45°	Quintary Grout Hole, 45° Angle
△G-1		Exploratory Drill Holes
⊙ 106		Construction Grout Holes

SCALE: 1 INCH=5 FEET
5' 0 5'

THIS DRAWING HAS BEEN REDUCED TO
THREE-EIGHTHS THE ORIGINAL SCALE

REVISIONS

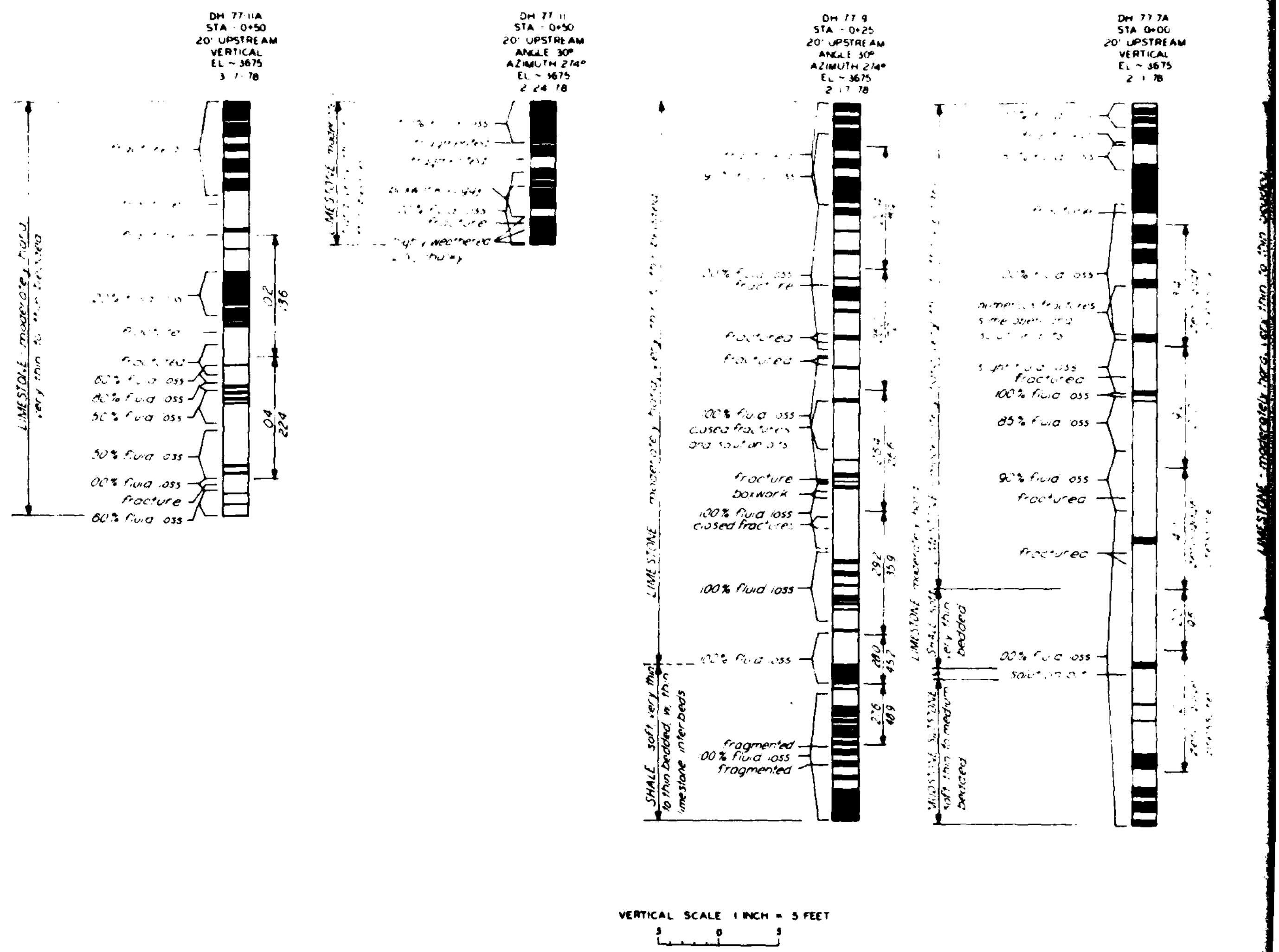
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

FALL RIVER BASIN
COLD BROOK DAM - HOT SPRINGS, SO. DAK.
EXTEND GROUT CURTAIN
PLAN OF GROUT HOLES
EXPLORATORY BORINGS AND
CONSTRUCTION GROUT HOLES

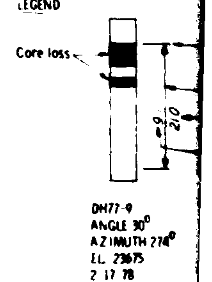
DACA45

SAFETY PAYS

THIS PLAN ACCOMPANIES CONTRACT NO.
DACA45 MODIFICATION NO.

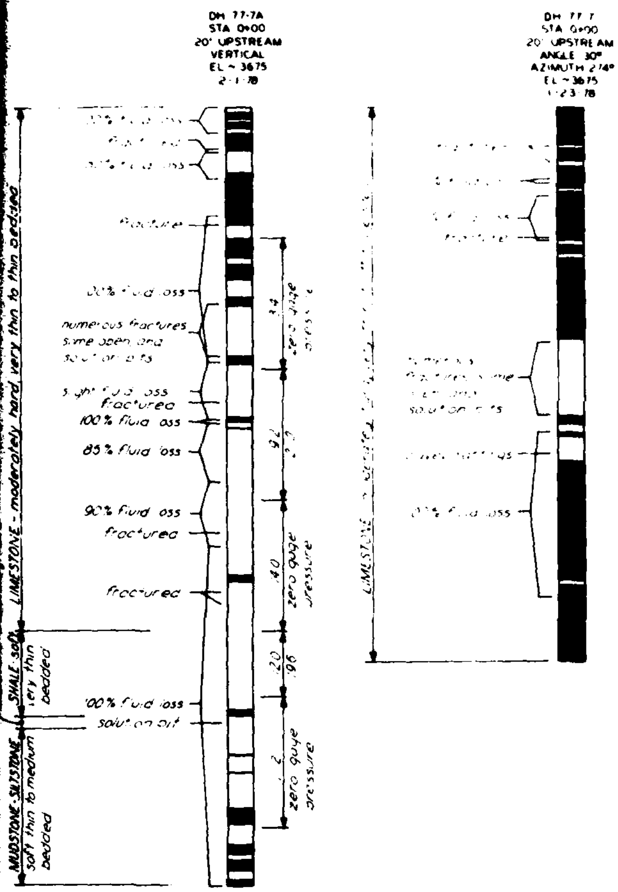


LEGEND

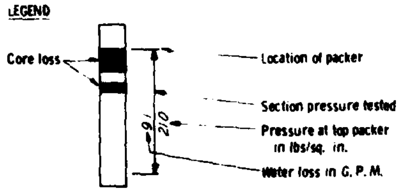


BEDROCK TERMS

Very Hard - cannot be scratch
Hard - difficult to scratch with
Moderately Hard - cannot be
easily with
Soft - can be scratched with
Very Thin Bedded - thickness
Thin Bedded - thickness of be
Medium Bedded - thickness



LEGEND



DH77-9	Hole number
ANGLE 30°	Inclination of hole from vertical
AZIMUTH 274°	Direction of inclination
EL 23675	Surface elevation
2-17-78	Date completed

BEDROCK TERMS

Very Hard - cannot be scratched with knife.
Hard - difficult to scratch with knife.
Moderately Hard - cannot be scratched with fingernail, can be scratched easily with knifeblade.
Soft - can be scratched with fingernail.
Very Thin Bedded - thickness of beds ≤ 1/4
Thin Bedded - thickness of beds < 1/2'
Medium Bedded - thickness of beds < 3'

NOTES:

1. See Plate 2 for boring locations.
2. Drill Holes DH 77-11A and DH 77-7A are vertical. Drill holes DH 77-11, DH 77-9 and DH 77-7 are at an angle of 30° from vertical. These borings are not shown in their true relationship to each other.
3. Exact position of lost core is unknown. Approximate position is shown diagramatically.
4. Borings DH 77-7 thru DH 77-11A were with a Longyear Rotary Drill Rig using a 3½" casing bit wireline) and 3" core bbl.

SAFETY PAYS

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

DATE	DESCRIPTION	MADE	APPR'D

REVISIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

FALL RIVER BASIN
COLD BROOK DAM - HOT SPRINGS, SO DAK
EXTEND GROUT CURTAIN
CONDENSED LOGS OF BORINGS
AND WATER PRESSURE TESTS

DRAWN BY: J L C

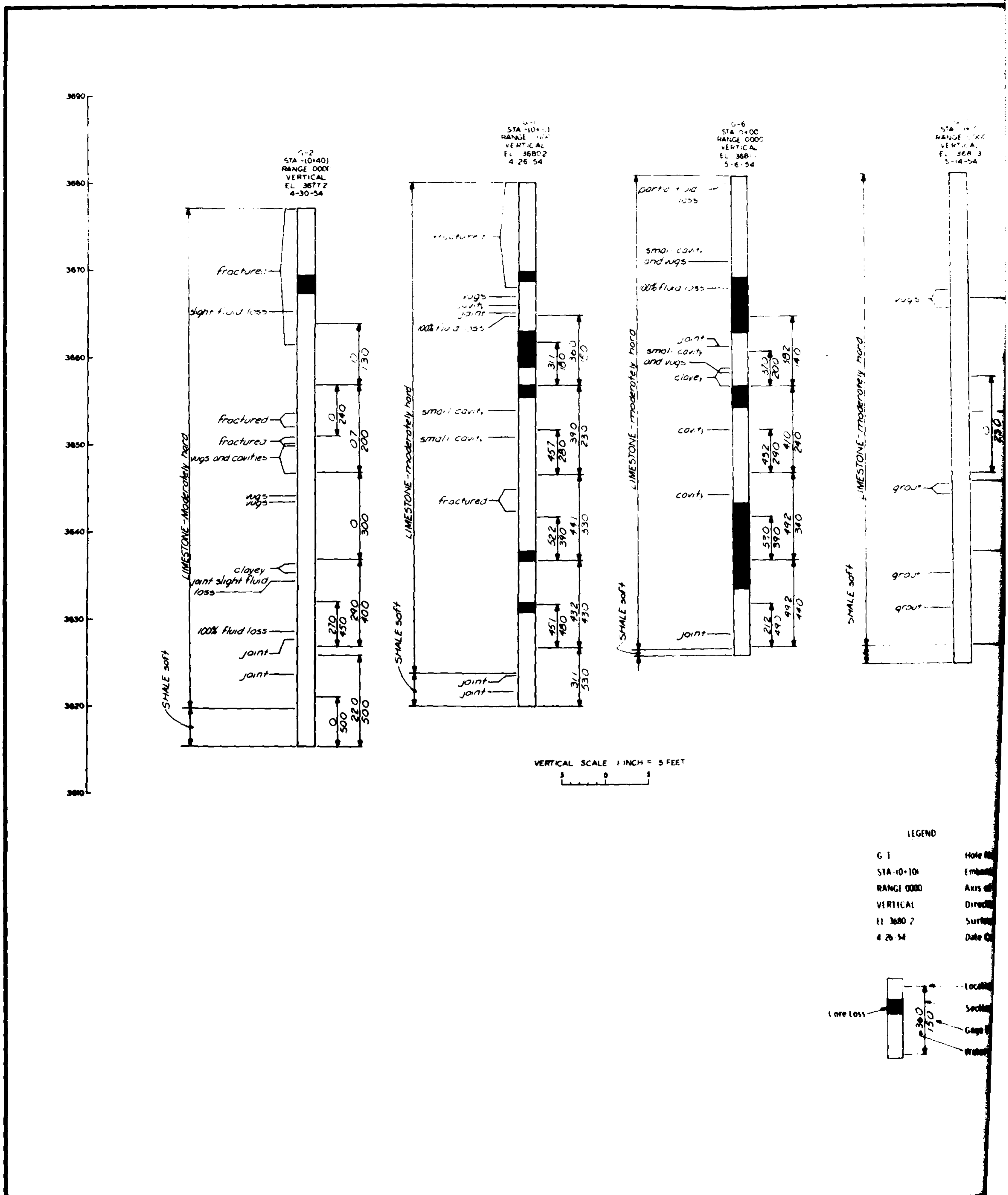
CHIEF GEOLOGY SECTION

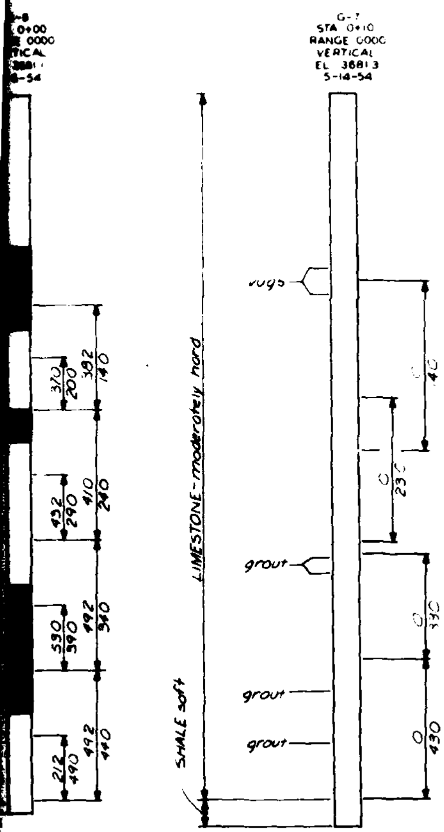
SCALE AS SHOWN

DACW 45

THIS PLAN ACCOMPANIES CONTRACT NO.
MODIFICATION NO.

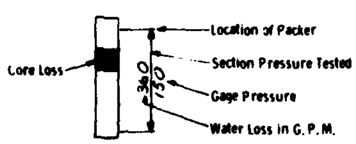
2


G-2
STA -(0+40)
RANGE 000(
VERTICAL
EL 3677.2
4-30-54
STA -(0+( )
RANGE
VERTICAL
EL 3680.2
4-26-54
G-6
STA 0+00
RANGE 0000
VERTICAL
5-6-54
5-14-54
fractures
slight fluid loss
fractured
vugs and cavities
vugs
clayey
joint slight fluid loss
100% fluid loss
joint
SHALE soft
LIMESTONE-Moderately hard
vugs
joint
100% fluid loss
small cavity
fractured
LIMESTONE-moderately hard
small cavity and vugs
100% fluid loss
clayey
cavity
grout
VERTICAL SCALE 1 INCH = 5 FEET
LEGEND
G 1
STA -(0+10)
RANGE 0000
VERTICAL
EL 3680.2
4 26 54
Hole
Axis
Core Loss



LEGEND

G-1	Hole Number
STA-(0+10)	Embankment Station
RANGE 0000	Axis of Dam
VERTICAL	Direction of Hole
EL. 3680.2	Surface Elevation
4-28-54	Date Completed



NOTE

1. BORINGS NOT SHOWN IN HORIZONTAL RELATIONSHIP TO EACH OTHER.
2. See Plate 2 for Boring Locations.

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

DATE	DESCRIPTION	MADE	APPR'D

REVISIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

FALL RIVER BASIN
COLD BROOK DAM - HOT SPRINGS SO DAK.
EXTEND GROUT CURTAIN
CONDENSED LOGS OF BORINGS AND WATER PRESSURE TESTS

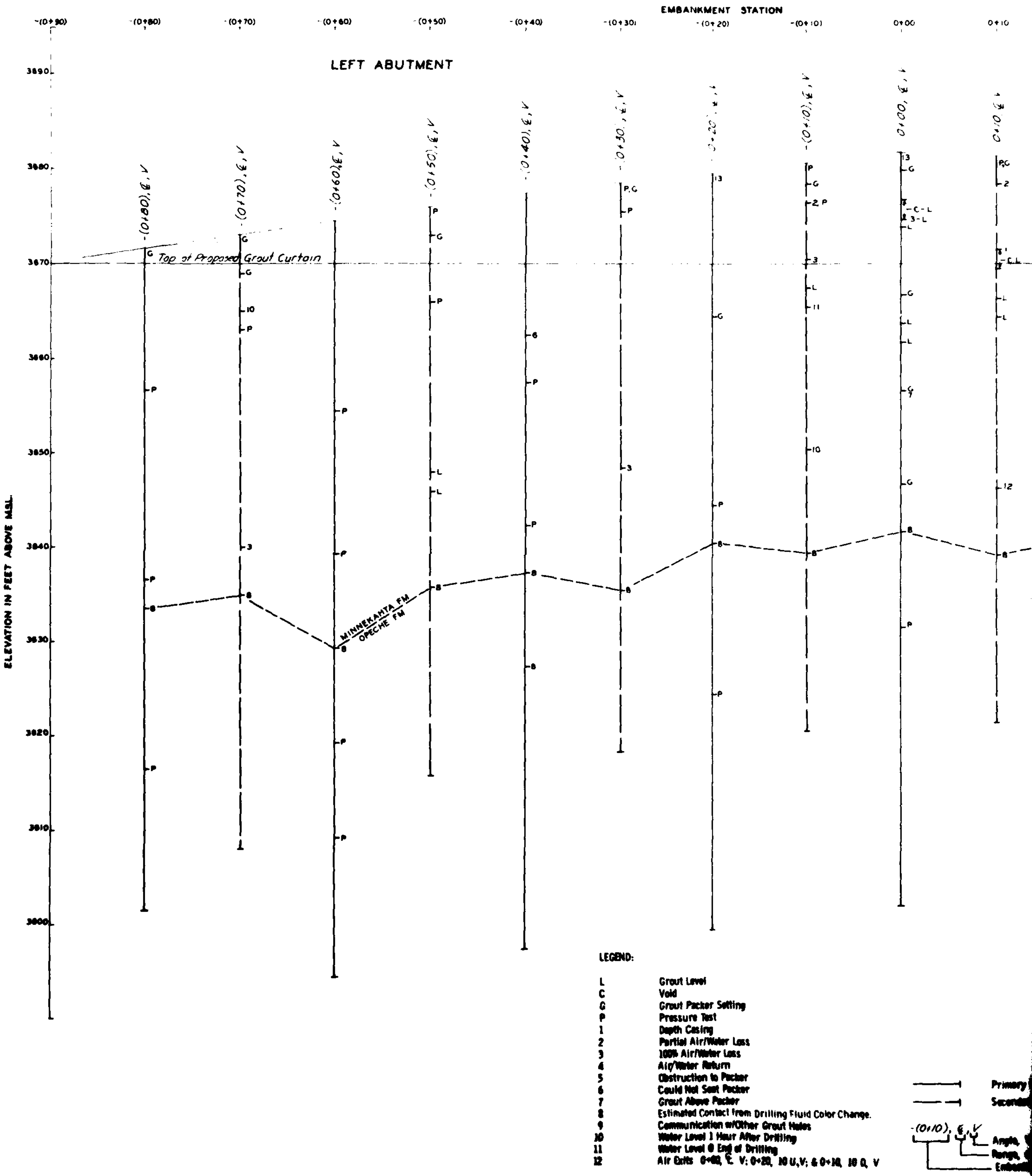
SCALE AS SHOWN

DACW4

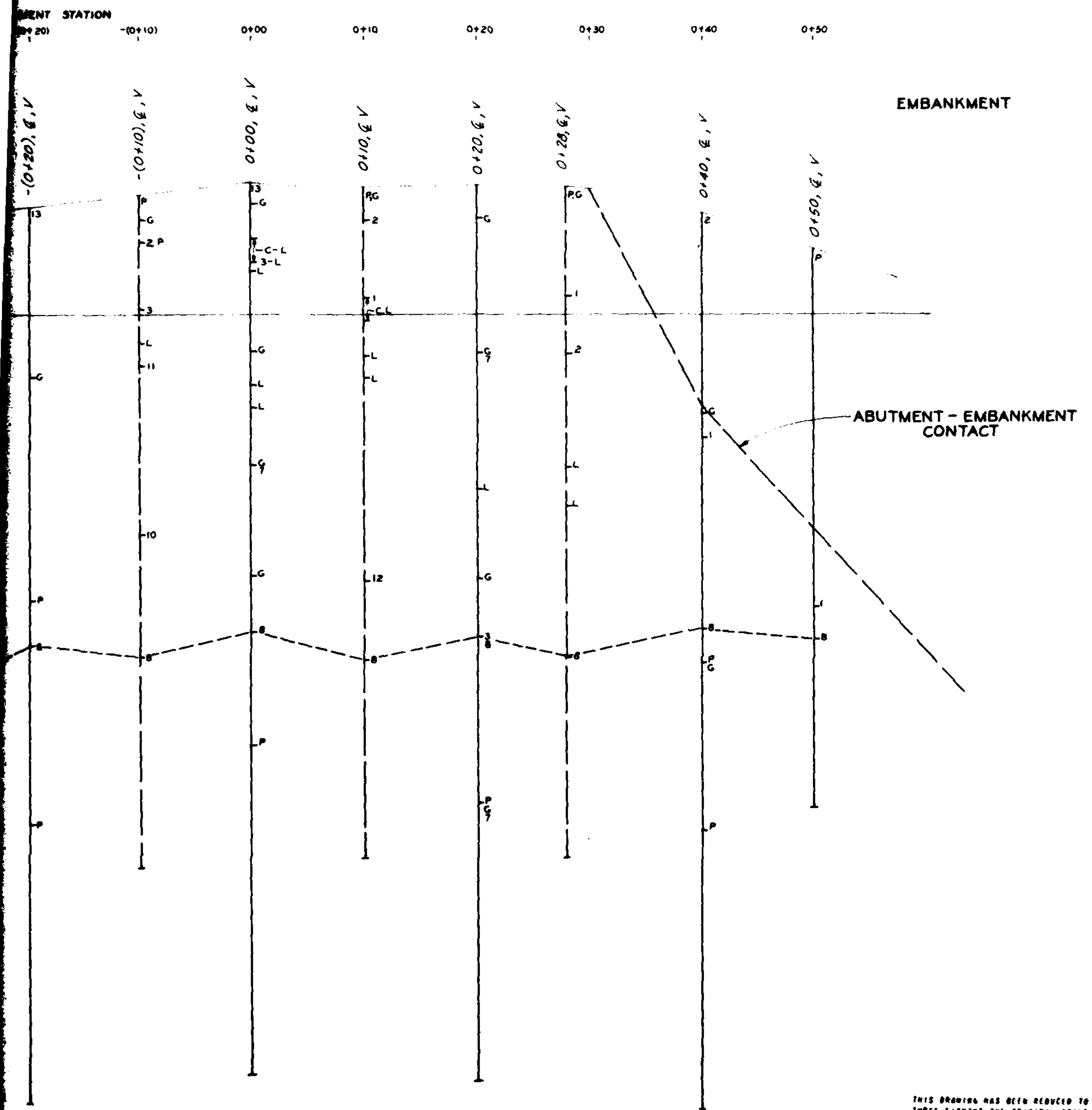
THIS PLAN ACCOMPANIED CONTRACT NO.
MODIFICATION NO.

SAFETY PAYS

2



EMBANKMENT STATION
LEFT ABUTMENT
ELEVATION IN FEET ABOVE MSL
Top of Proposed Grout Curtain
MINNEKAHTA FM
OPECHE FM
LEGEND:
L Grout Level
C Void
G Grout Packer Setting
P Pressure Test
1 Depth Casing
2 Partial Air/Water Loss
3 100% Air/Water Loss
4 Air/Water Return
5 Obstruction to Packer
6 Could Not Seat Packer
7 Grout Above Packer
8 Estimated Contact from Drilling Fluid Color Change.
9 Communication w/Other Grout Holes
10 Water Level 1 Hour After Drilling
11 Water Level @ End of Drilling
12 Air Exits 0+00, ℄ V; 0+20, 10 U,V; & 0+10, 10 D, V



THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

Packer Setting
Test
Water Loss
Water Loss
Return
to Packer
Seat Packer
Packer
Contact from Drilling Fluid Color Change.
w/Other Grout Holes
3 Hour After Drilling
@ End of Drilling
0+00, ℄, V; 0+20, 10 U,V; & 0+10, 10 D, V

Primary Grout Hole
Secondary Grout Hole

-(0+10), ℄, V
Angle, Vertical
Range, on Centerline of Dam
Embankment Station

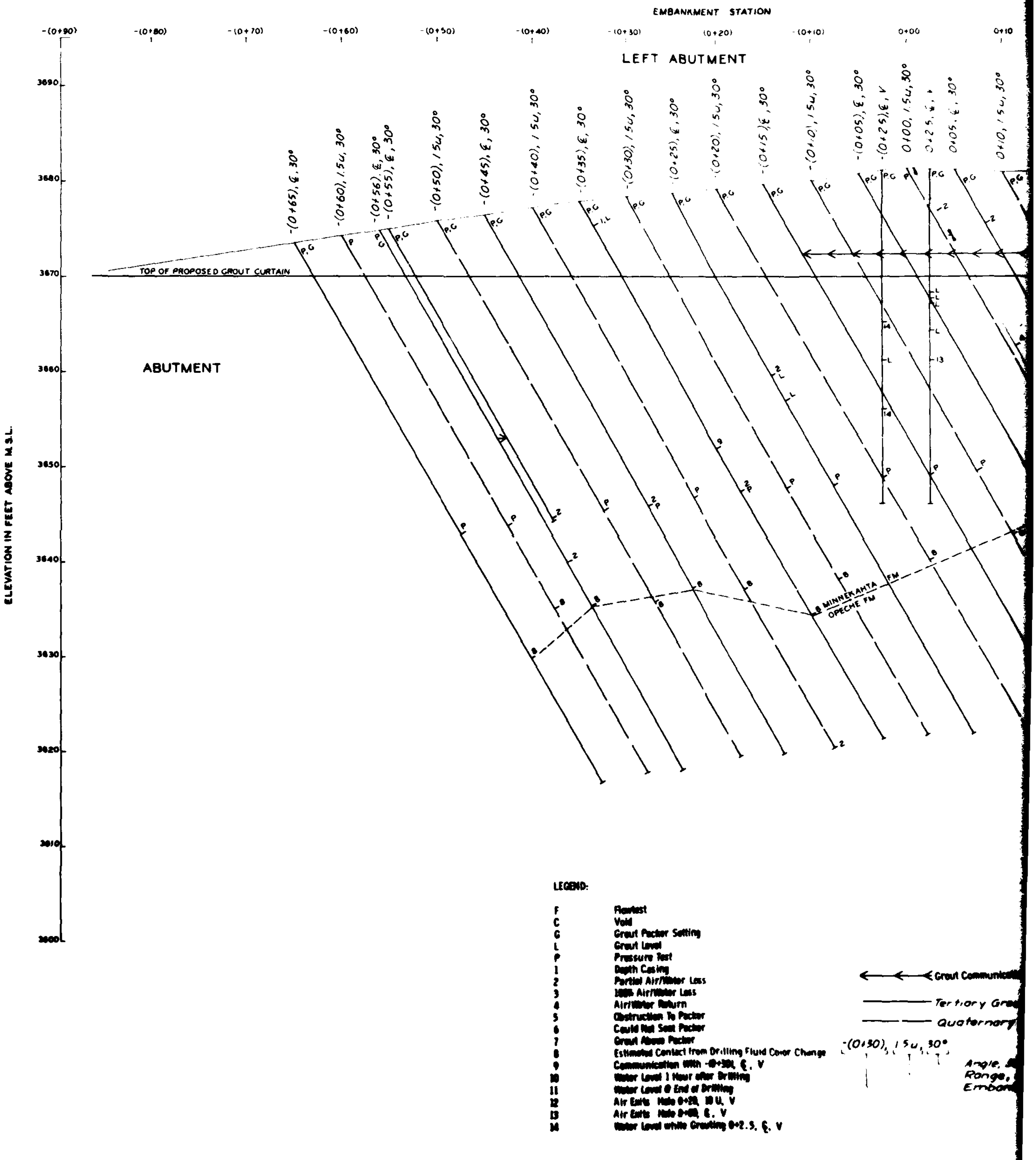
REVISIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

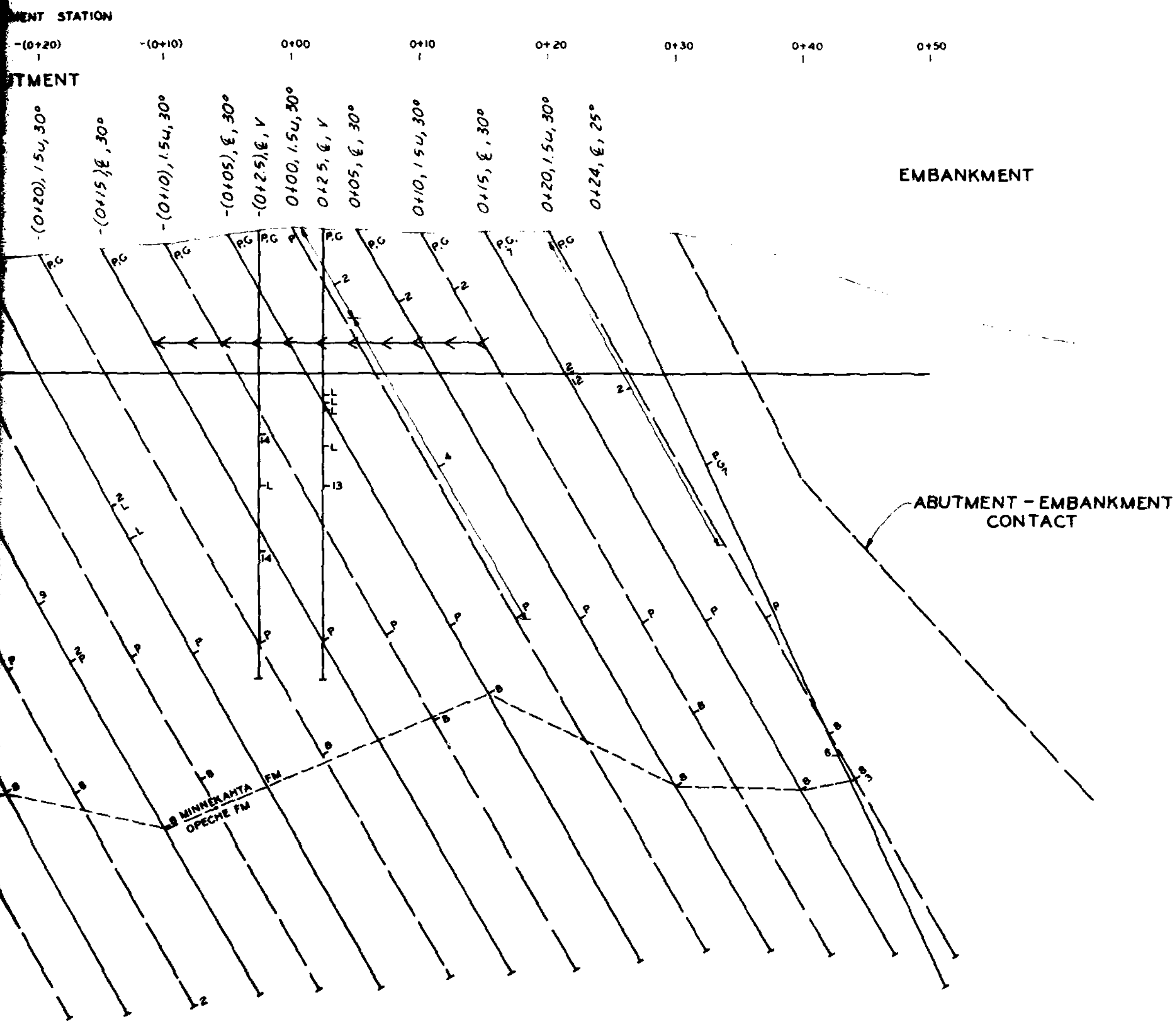
FALL RIVER BASIN
COLD BROOK DAM - HOT SPRINGS SO. DAK.
EXTEND GROUT CURTAIN
PROFILE ALONG LINE OF PRIMARY & SECONDARY GROUT HOLES

GEOLOGY

SAFETY PAYS


EMBANKMENT STATION
-(0+90)
-(0+80)
-(0+70)
-(0+60)
-(0+50)
-(0+40)
-(0+30)
(0+20)
-(0+10)
0+00
0+10
LEFT ABUTMENT
ELEVATION IN FEET ABOVE M.S.L.
3690
3680
3670
3660
3650
3640
3630
3620
3610
3600
TOP OF PROPOSED GROUT CURTAIN
ABUTMENT
MINNEKAHTA FM
OPECHE FM
LEGEND:
F Flowtest
C Void
G Grout Packer Setting
L Grout Level
P Pressure Test
1 Depth Casing
2 Partial Air/Water Loss
3 100% Air/Water Loss
4 Air/Water Return
5 Obstruction To Packer
6 Could Not Seat Packer
7 Grout Above Packer
8 Estimated Contact from Drilling Fluid Color Change
9 Communication With -0+30, ℄, V
10 Water Level 1 Hour after Drilling
11 Water Level @ End of Drilling
12 Air Exits Hole 0+20, 10 U, V
13 Air Exits Hole 0+00, ℄, V
14 Water Level while Grouting 0+2.5, ℄, V
Grout Communicati
Tertiary Gro
Quaternary
-(0+30), 1.5u, 30°
Angle,
Range,
Embank

1



Grout Communication

Tertiary Grout Holes

Quaternary Grout Holes

-(0+30), 1.5u, 30°

Angle, 30° from Vertical

Range, 1.5 feet upstream

Embankment Station

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

REVISIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

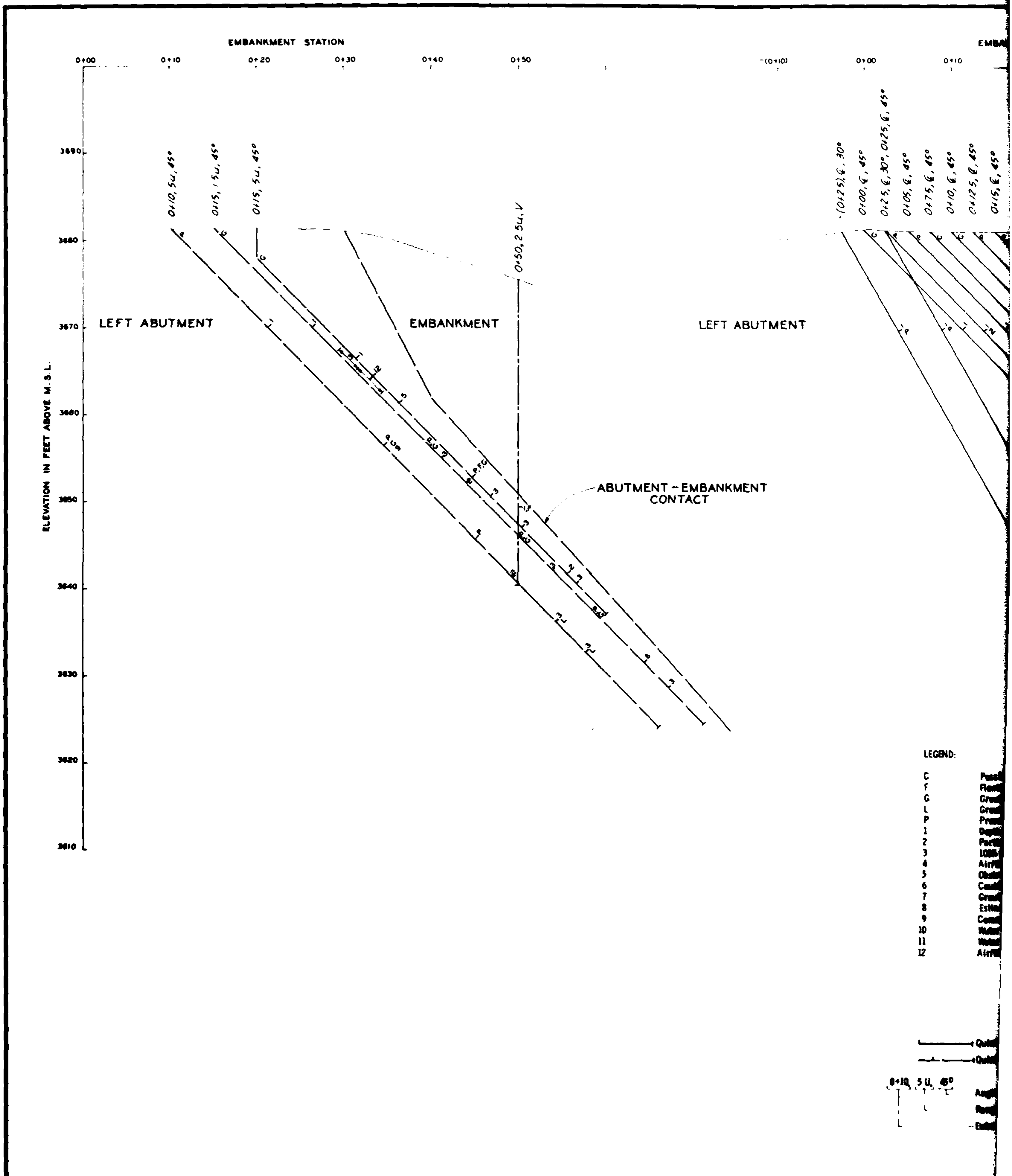
FALL RIVER BASIN
COLD BROOK DAM - HOT SPRINGS, SO. DAK.

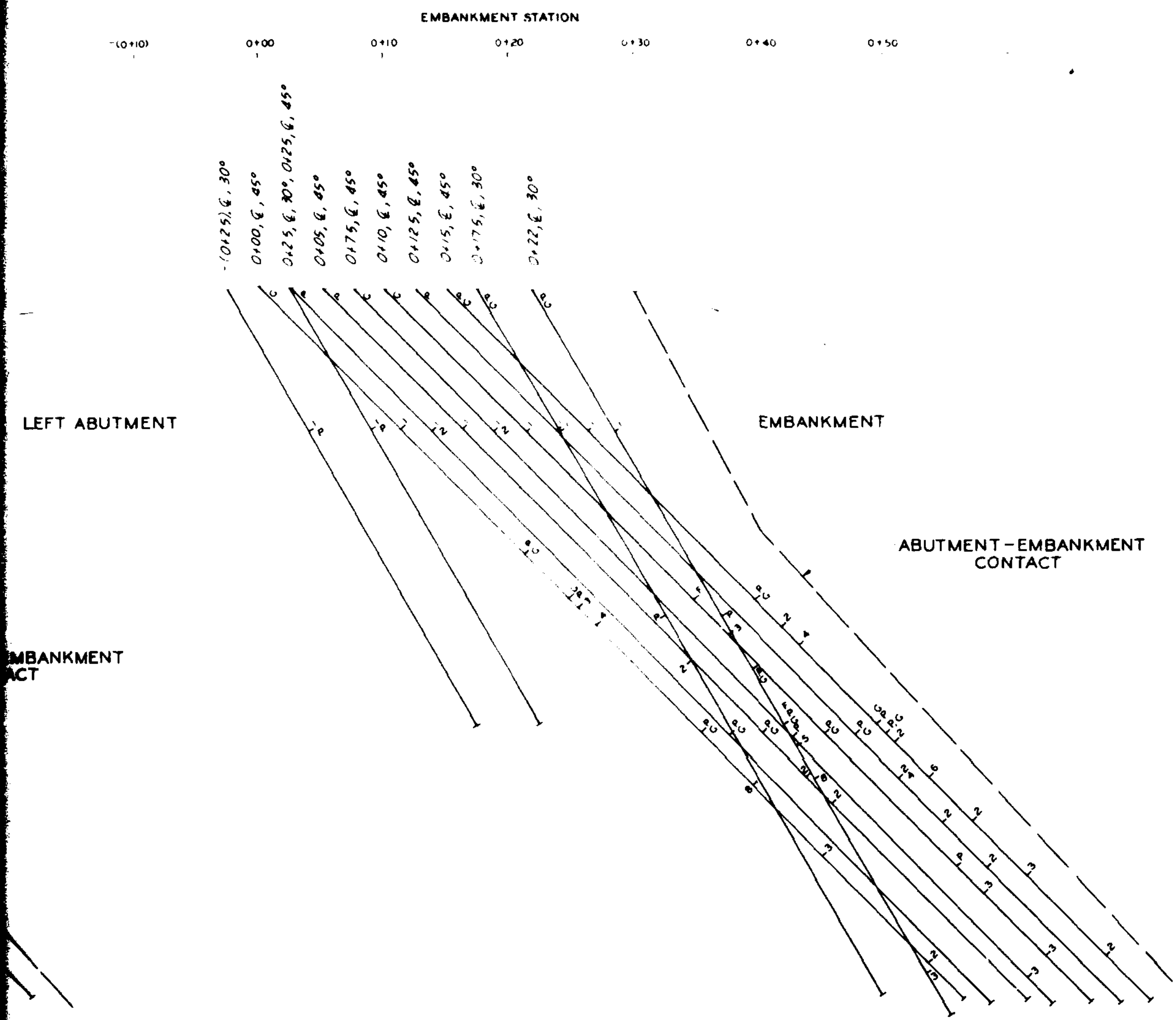
EXTEND GROUT CURTAIN
PROFILE ALONG TERTIARY AND QUATERNARY GROUT HOLES

SCALE: AS SHOWN

SAFETY PAYS

THIS PLAN ACCOMPANIES CONTRACT
DACA45


EMBANKMENT STATION
0+00
0+10
0+20
0+30
0+40
0+50
-(0+10)
0+00
0+10
ELEVATION IN FEET ABOVE M.S.L.
3690
3680
3670
3660
3650
3640
3630
3620
3610
0+10, 5u, 45°
0+15, 15u, 45°
0+15, 5u, 45°
0+50, 2.5u, V
-(0+25), ℄, 30°
0+00, ℄, 45°
0+25, ℄, 30°, 0+25, ℄, 45°
0+05, ℄, 45°
0+75, ℄, 45°
0+10, ℄, 45°
0+125, ℄, 45°
0+15, ℄, 45°
LEFT ABUTMENT
EMBANKMENT
LEFT ABUTMENT
ABUTMENT - EMBANKMENT CONTACT
LEGEND:
C
F
G
L
P
1
2
3
4
5
6
7
8
9
10
11
12
0+10, 5 U, 45°



LEGEND:

C Possible Clay Filled Void
F Flowtest
G Grout (Packer Setting)
L Grout Level
P Pressure Test
1 Depth Casing
2 Partial Air/Water Loss
3 100% Air/Water Loss
4 Air/Water Return
5 Obstruction to Packer
6 Could Not Seat Packer
7 Grout Above Packer
8 Estimated Contact from Drilling Fluid Color Change
9 Communication w/0+12.5, ℄, 45°
10 Water Level 1 Hour After Drilling
11 Water Level @ End of Drilling
12 Air/Water Exits Out 0+20, 10 U, V

Quintary Holes, Centerline
Quintary Holes, Upstream of Centerline

0+10, 5 U, 45°
— Angle, 45° from Vertical
— Range, 5 feet Upstream
— Embankment Station

SAFETY PAYS

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

DATE	DESCRIPTION	MADE	APPR'D

REVISIONS

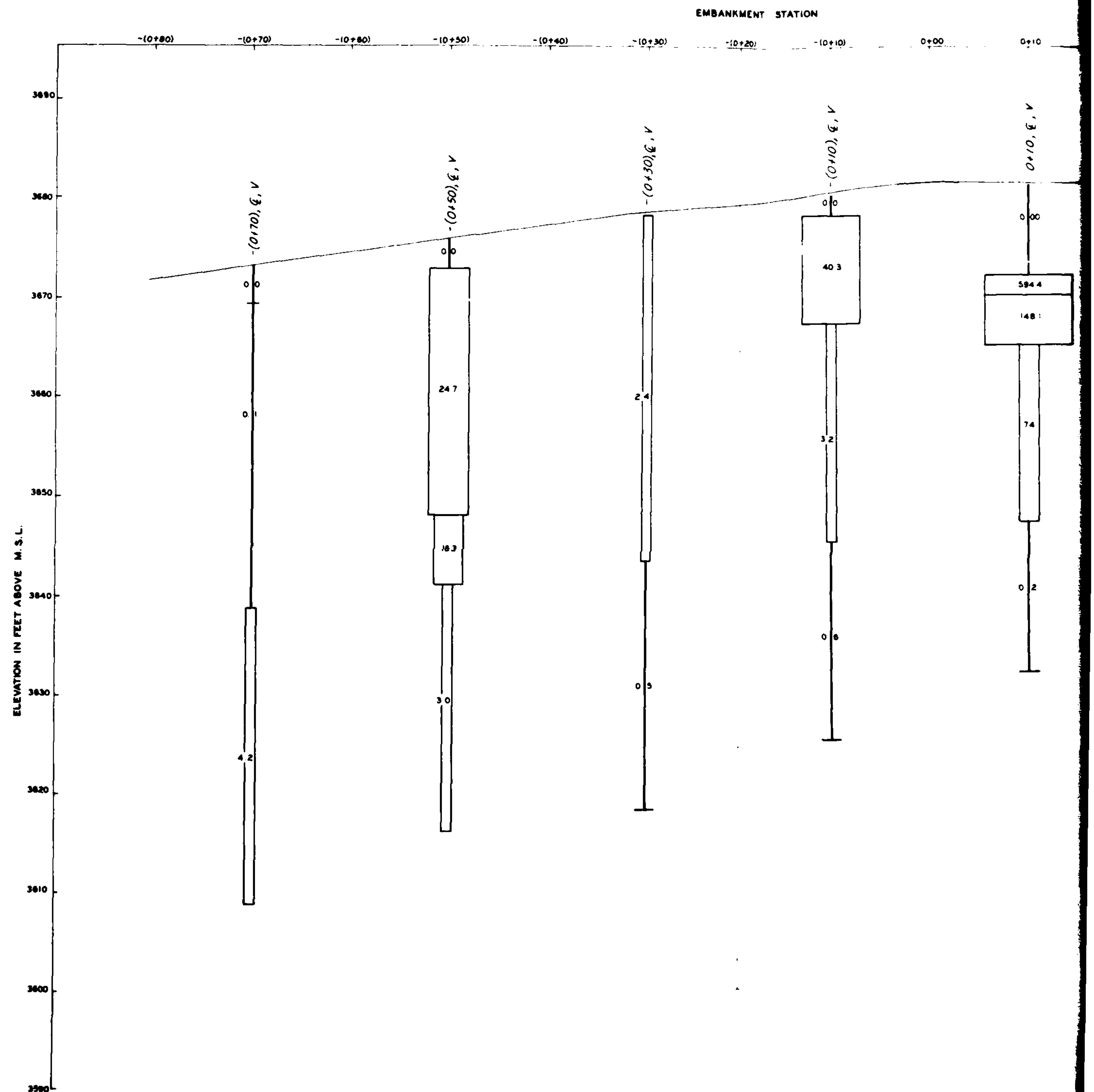
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

DESIGNED BY:
DRAWN BY: J.L.F
CHECKED BY:
SUBMITTED BY:
CHIEF GEOLOGY SECTION

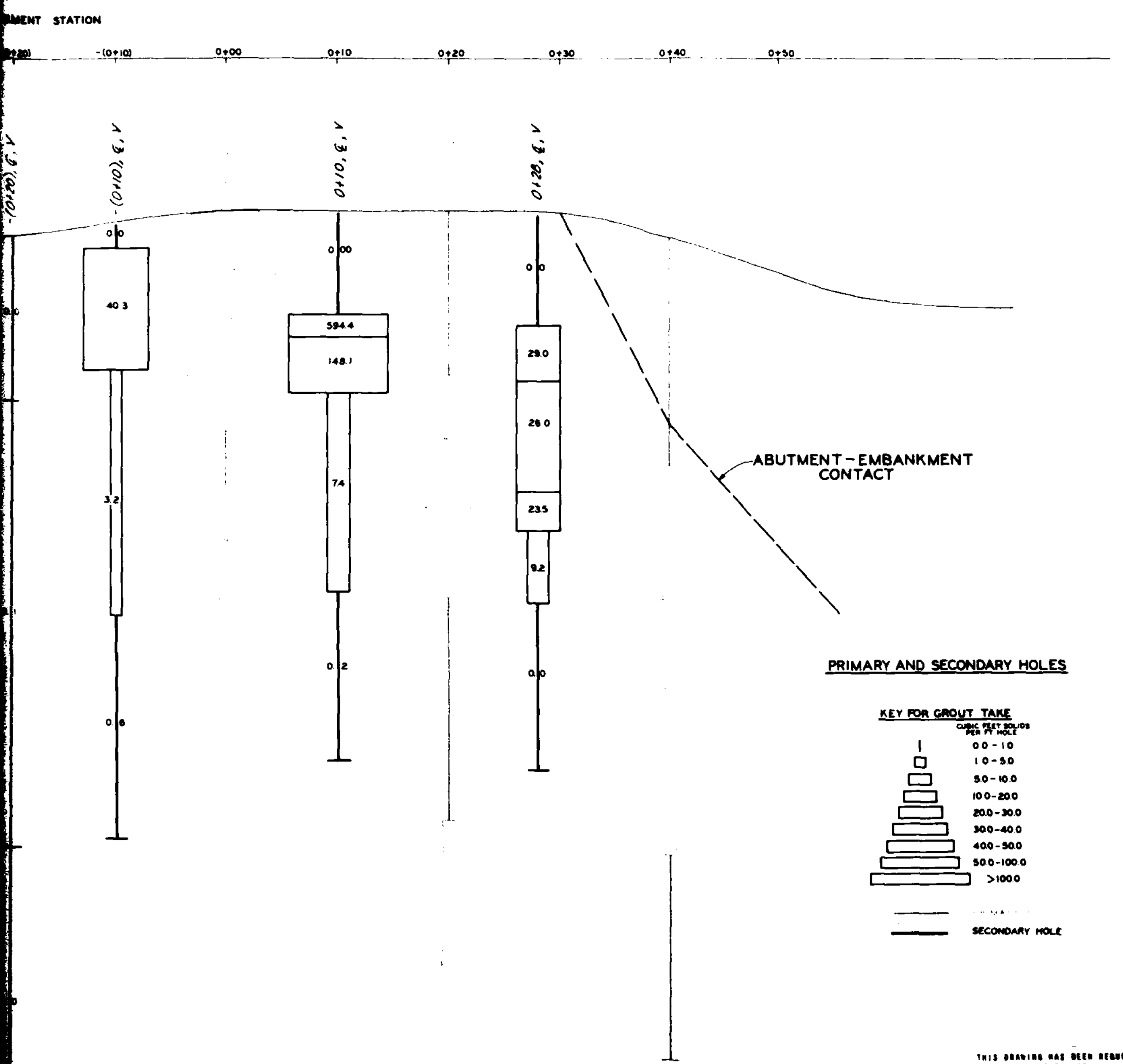
FALL RIVER BASIN
COLD BROOK DAM – HOT SPRINGS, SO. DAK.
EXTEND GROUT CURTAIN
PROFILE ALONG QUINTARY GROUT HOLES

SCALE AS SHOWN
SPEC. NO. DACA45

THIS PLAN ACCOMPANIES CONTRACT NO. DACA45 MODIFICATION NO.



EMBANKMENT STATION
-(0+80)
-(0+70)
-(0+60)
-(0+50)
-(0+40)
-(0+30)
-(0+20)
-(0+10)
0+00
0+10
ELEVATION IN FEET ABOVE M.S.L.
3690
3680
3670
3660
3650
3640
3630
3620
3610
3600
3590
-(0+70), ℄, V
-(0+50), ℄, V
-(0+30), ℄, V
-(0+10), ℄, V
0+10, ℄, V
0.0
0.1
4.2
0.0
24.7
18.3
3.0
2.4
0.5
0.0
40.3
3.2
0.6
0.00
594.4
148.1
7.4
0.2



THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

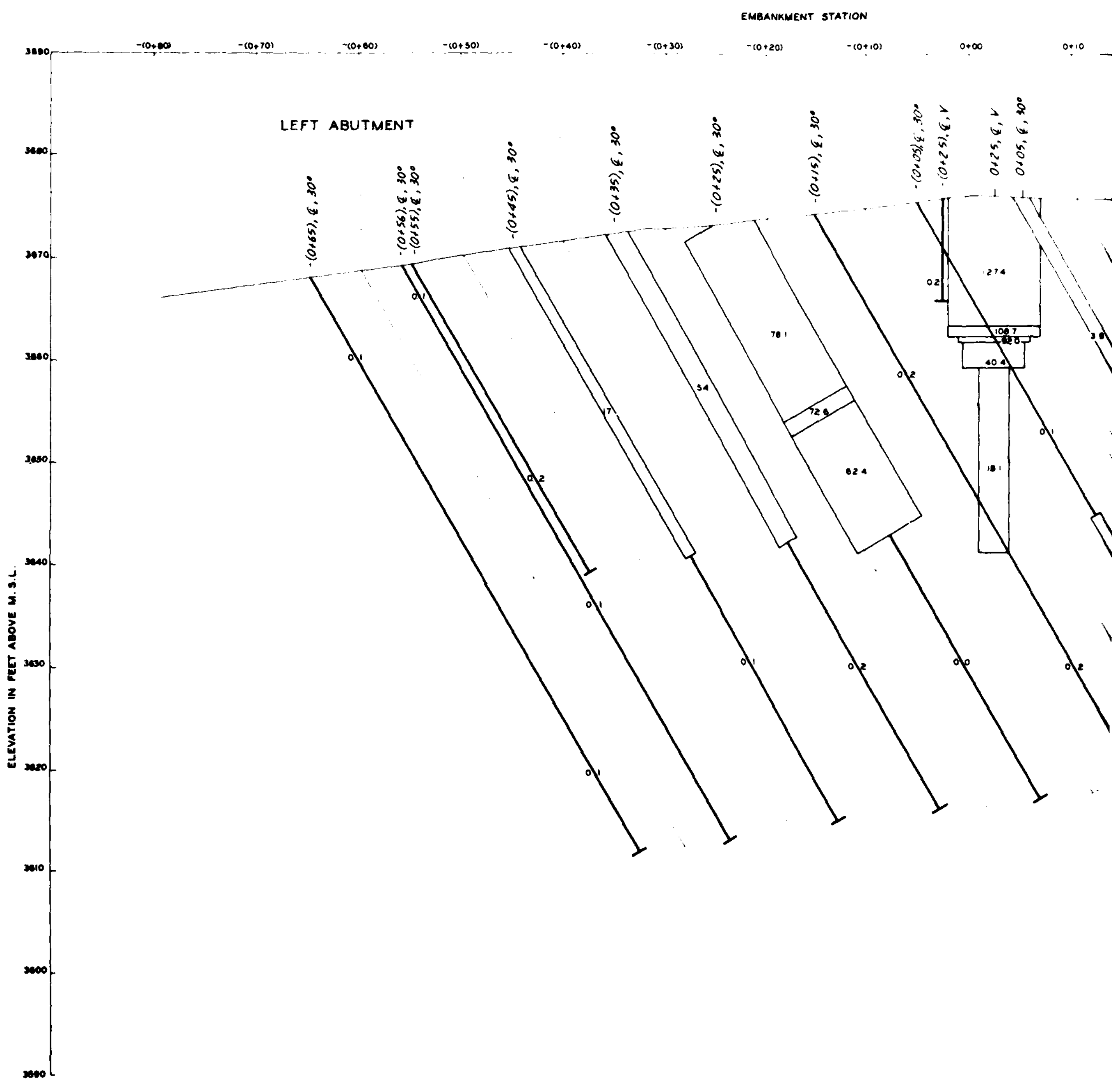
REVISIONS

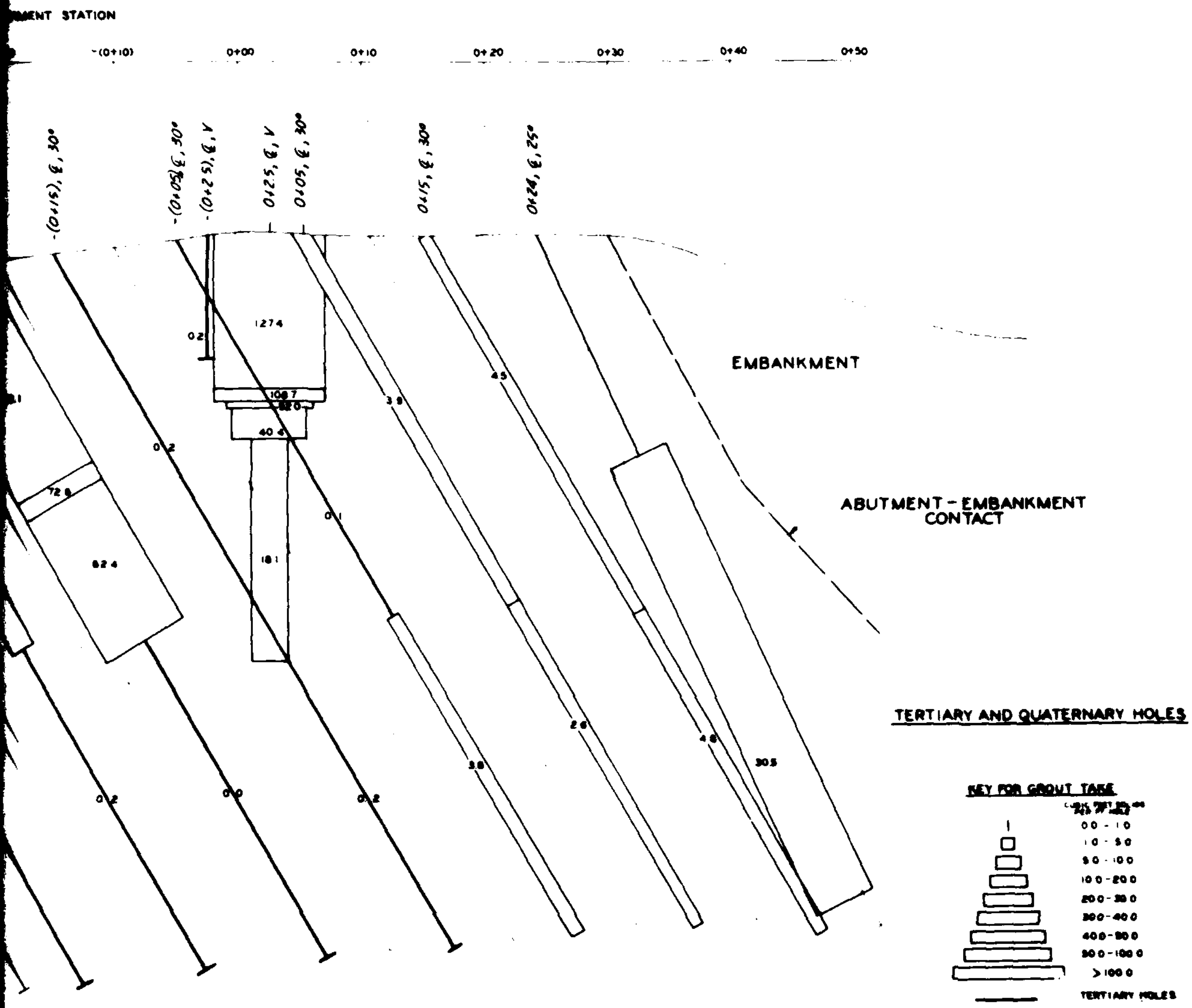
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

FALL RIVER BASIN
COLD BROOK DAM - HOT SPRINGS, SO. DAK.
EXTEND GROUT CURTAIN
PRIMARY & SECONDARY HOLES
GROUT TAKES

SAFETY PAYS

THIS PLAN ACCOMPANIES CONTRACT NO.
DACA45 MODIFICATION NO.


EMBANKMENT STATION
-(0+80)
-(0+70)
-(0+60)
-(0+50)
-(0+40)
-(0+30)
-(0+20)
-(0+10)
0+00
0+10
LEFT ABUTMENT
ELEVATION IN FEET ABOVE M.S.L.
3690
3680
3670
3660
3650
3640
3630
3620
3610
3600
3590
-(0+65), ℄, 30°
-(0+45), ℄, 30°



THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE

REVISIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

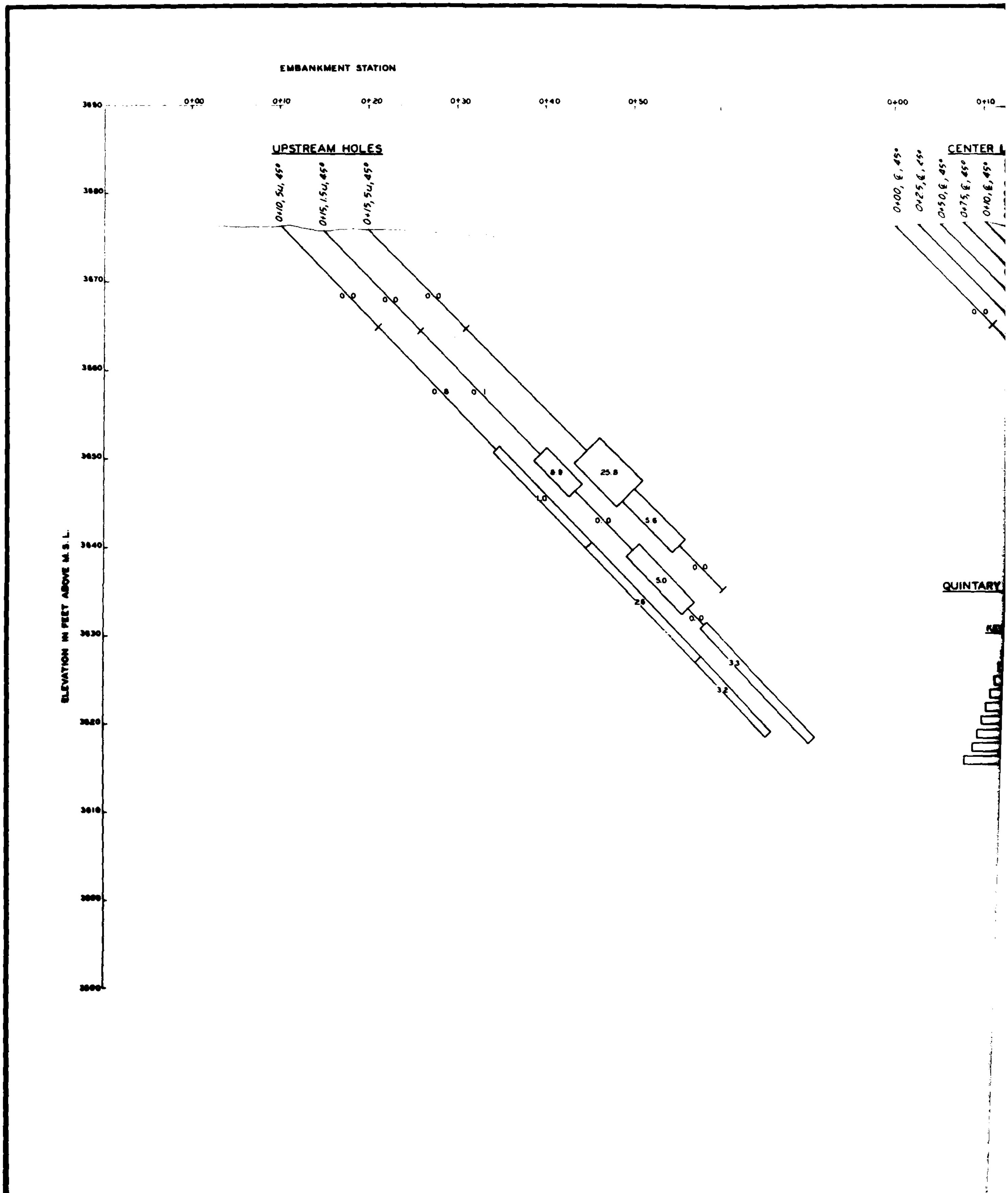
FALL RIVER BASIN
COLD BROOK DAM - HOT SPRINGS, SO. DAK.
EXTEND GROUT CURTAIN
TERTIARY AND QUATERNARY HOLES
GROUT TAKES

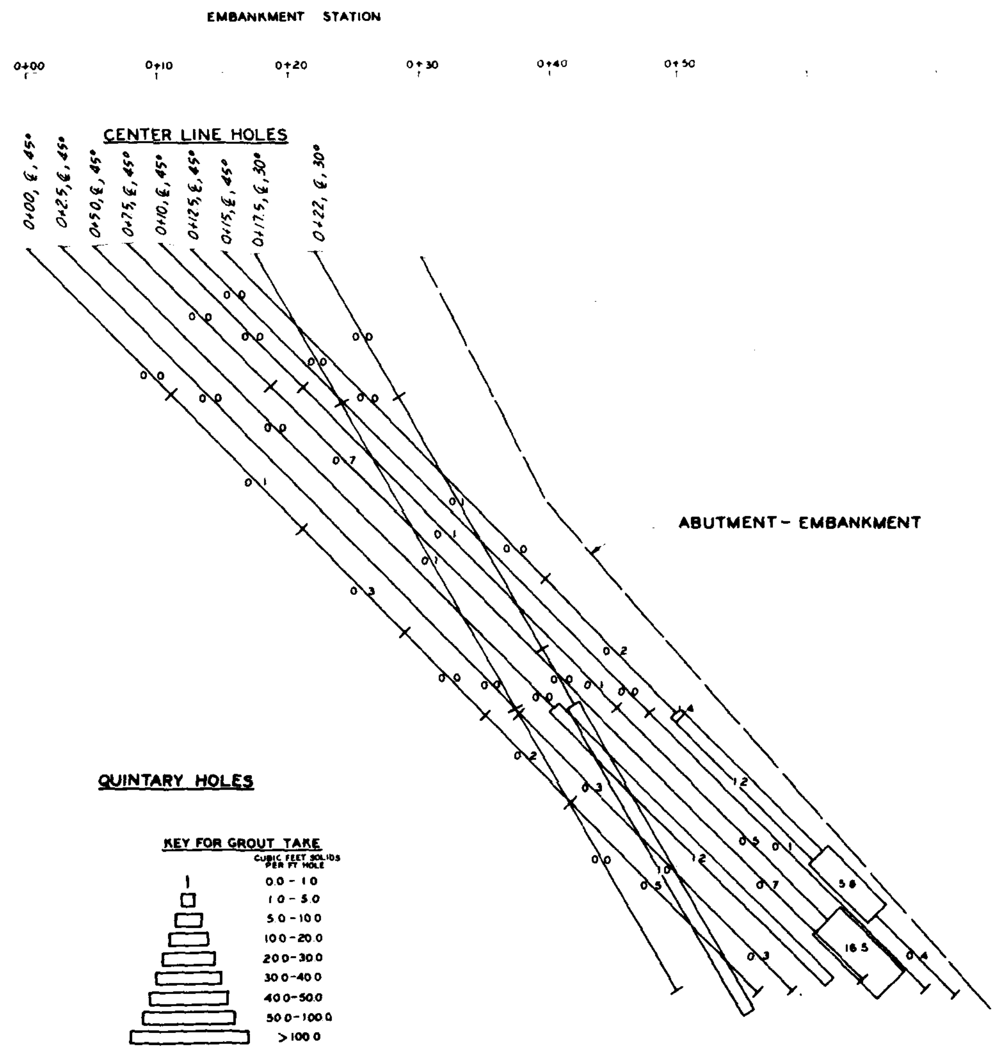
SAFETY PAYS

THIS PLAN ACCOMPANIES CONTRACT NO.

- THINK VALUE ENGINEERING -

2


EMBANKMENT STATION
0+00
0+10
0+20
0+30
0+40
0+50
UPSTREAM HOLES
0+10, 5U, 45°
0+15, 1.5U, 45°
0+15, 5U, 45°
CENTER L
0+00, ℄, 45°
0+25, ℄, 45°
0+50, ℄, 45°
0+75, ℄, 45°
0+10, ℄, 45°
QUINTARY
ELEVATION IN FEET ABOVE M. S. L.
3690
3680
3670
3660
3650
3640
3630
3620
3610
3600
25.8
5.6
5.0
1.0
2.8
3.3
3.2



THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

REVISIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

FALL RIVER BASIN
COLD BROOK DAM – HOT SPRINGS, SO. DAK.
EXTEND GROUT CURTAIN
QUINTARY HOLE GROUT TAKES

THIS PLAN ACCOMPANIES CONTRACT NO.

2

ATE

LMED